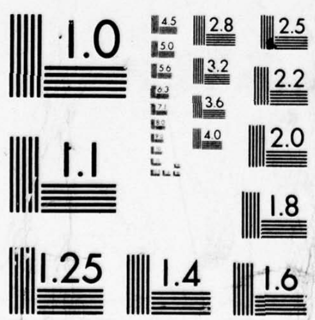
AD-A034 655 LITTLE (ARTHUR D) INC CAMBRIDGE MASS F/G 5/2
DEVELOPMENT OF CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM (CH--ETC(U)
OCT 76 D S ALLAN, G H HARRIS DOT-CG-24655-A
UNCLASSIFIED ADL-C-74685 USCG-D-117-76 NL

1 OF 3
AD
A034655

03465



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

REPORT NO. CG-D-117-76

12

DEVELOPMENT OF CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM (CHRIS)

OCTOBER 1976

Document is available to the U.S. Public through the
National Technical Information Service,
Springfield, Virginia 22161

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION

UNITED STATES COAST GUARD

OFFICE OF RESEARCH AND DEVELOPMENT

WASHINGTON, D.C. 20590

NOTICE

This document is disseminated under the sponsorship of the U. S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
(18) USCG-D-117-76 (19)		

4. Title and Subtitle	5. Report Date
(6) Development of Chemical Hazards Response Information System (CHRIS)	(11) Oct[redacted]76
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s)	(14) ADL-C-24685
(10) D. S. Allan [redacted] G. H. Harris	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Arthur D. Little, Inc. Acorn Park Cambridge, Massachusetts (12) 207p.	4430
	11. Contract or Grant No.
	(15) DOT-CG-24,655-A
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Coast Guard (G-DSA-1/TP44) Washington, D. C.	(9) Final Rep[redacted].
	14. Sponsoring Agency Code

15. Supplementary Notes

The U. S. Coast Guard Office of Research and Development's technical representatives for the work performed herein were Drs. Michael C. Parnarouskis and John M. Cece.

16. Abstract

This report summarizes the development of the major components of the Chemical Hazards Response Information System (CHRIS). It also describes specific studies that were conducted as part of the CHRIS program during the development phase. The reporting of the development of CHRIS is particularly appropriate at this time since the complete system has only recently been made available to Coast Guard users. The system will be carefully evaluated during the first year that it is in use, and the results of this utilization study will be reported on at a later date.

17. Key Words	18. Distribution Statement
CHRIS, Chemical Hazards Information System Response Chemical Discharges	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	208	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

208850
LB

DEVELOPMENT OF CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM (CHRIS)

Final Report

Prepared for

Commandant
United States Coast Guard
The Department of Transportation
Washington, DC 20590

by

Arthur D. Little, Inc.
Cambridge, MA 02140

under Contract No. DOT-CG-24,655-A

C-74685

October 1976

TABLE OF CONTENTS

	Page
List of Figures	v
List of Tables	vi
Acknowledgements	vii
1.0 EXECUTIVE SUMMARY	1
1.1 Introduction	1
1.2 The Development of CHRIS	1
1.3 Current and Future Work	3
1.4 Development Procedures	3
1.5 Product of the CHRIS Development	4
2.0 THE PRELIMINARY AND FINAL DESIGN OF CHRIS	6
2.1 General	6
2.2 The Preliminary Design of CHRIS	6
2.3 The Results of the CHRIS Development	8
3.0 CONCLUSIONS AND RECOMMENDATIONS	9
3.1 Major Conclusions and Recommendations	9
3.2 General Recommendations	12
4.0 CHRIS COMPONENTS	15
4.1 Condensed Guide to Chemical Hazards, CG-446-1	15
4.2 Hazardous Chemical Data, CG-446-2	25
4.3 Hazard Assessment Handbook, CG-446-3	38
4.4 Response Methods Handbook, CG-446-4	49
4.5 Hazard Assessment Computer System (HACS)	58
4.6 Regional Contingency Plan Data Base	67
5.0 CHRIS TRAINING	81
5.1 Scope and Content	81
5.2 Development Procedures and Considerations	82
5.3 Conclusions and Recommendations	87

TABLE OF CONTENTS

(Continued)

	Page
6.0 OTHER CHRIS RELATED STUDIES	89
6.1 Chemical Hazards Response Information System for Multimodal Accidents (CHRISMA)	89
6.2 A Survey Study to Select a Limited Number of Hazardous Materials to Define Amelioration Requirements	90
6.3 Inventory of Equipment and Agents for Responding to Marine Transportation Fires	92
REFERENCES	94
APPENDIX A - Schedule of Initiation and Completion of Major CHRIS Components	A-1
APPENDIX B - Supporting Information for CG-446-2, Hazardous Chemical Data	B-1
APPENDIX B-I - Preparation of Temperature Plots	B-1
APPENDIX B-II - Hazard Assessment Codes (Data Item 11)	B-8
APPENDIX B-III - Chemical Recognition Codes	B-15
APPENDIX B-IV - Data Sources	B-18
APPENDIX B-V - Methods Employed in Estimating Fire Hazard Data	B-24
APPENDIX C - Assessment Models in Support of the Hazard Assessment Handbook	C-1
Addendum (a) to Appendix C - Description of Hazard Assessment Models	C-10
APPENDIX D - Revised Specifications	D-1
APPENDIX D-I - Specifications for CG-446-1, Condensed Guide to Chemical Hazards (CHRIS)	D-1
Addemdum (a) to Appendix D-I - Standard Phrases	D-11

TABLE OF CONTENTS

(Continued)

	Page
Addendum (b) to Appendix D-I - Information on Explanation of Terms Reprinted from CG-446-1	D-22
APPENDIX D-II - CG-446-2, Hazardous Chemical Chemical Data Publication Specifications	D-29
APPENDIX D-III - Specifications for CG-446-3, Hazard Assessment Handbook	D-40

LIST OF FIGURES

	Page
Figure 1 - Data Sheet Layout	16
Figure 2 - Methyl Alcohol	18
Figure 3 - Hazard Assessment Tree: (Events Chart)	43
Figure 4 - Instructor's Note on the Condensed Guide to Chemical Hazards	83
Figure 5 - Note on the Chemistry of Hazardous Materials	84
Figure 6 - Key Biscayne	85
APPENDICES	
Figure B-V-1 - Minimum Ignition Temperatures of Hydrocarbons of Various Carbon Chain Lengths	B-25
Figure B-V-2 - Flammability Limits of Hydrocarbons	B-26
Figure B-V-3 - Weak Limit of Flammability of Various Organic Substances	B-26
Figure D-I-1 - A Condensed Guide to Chemical Hazards, CG-446-1 Table of Contents	D-2
Figure D-I-2 - Annotated Data Sheet	D-4
Figure D-I-3 - Data Sheet	D-9
Figure D-I-4 - Methyl Alcohol	D-10
Figure D-I-5 - Standard Phrases	D-12
Figure D-I-6 - Sample Update Control Sheet	D-33
Figure D-I-7 - Sample of Section II	D-34

LIST OF TABLES

	Page
Table 1 - Items Developed to Date Under the CHRIS Program	5
Table 2 - Hazard Assessment Handbook	40
Table 3 - Contents of a State Tab for a Regional Contingency Plan Data Base	70
Table 4 - Content of the Development Plan for Regional Contingency Plan Data Bases	76

APPENDICES

Table B-I-1 - Temperature Functions	B-4
Table B-II-1 - Code Selection Matrix	B-13

ACKNOWLEDGEMENTS

The development of the Chemical Hazards Response Information System (CHRIS) has resulted in a series of handbooks, reports, computer programs, and training aids that serve as the primary product of the development effort. This report describes the content of CHRIS and the general procedures employed in its development.

The development of CHRIS was conducted under the Marine Safety Branch, Division of Applied Technology, Office of Research and Development, U. S. Coast Guard. The Coast Guard project leader is Commander John Cece. Commander John Lindak was project leader during the preliminary system development and the early stages of the final system development. During the earlier work, additional guidance was provided by Commander Joseph Coburn.

We are indebted to many other Coast Guard personnel who have contributed in some way or another to the final product of this work. Important guidance and support were provided by Dr. Michael Parnarouskis of the Marine Safety Projects Branch and Lt. Cdr. George Brown, and Lt. Chris Willis of the Pollution Response Branch.

The Arthur D. Little, Inc. personnel who contributed to the development of the system include the following:

Project Director: Mr. D. S. Allan;

Technical Coordinator and Information Criteria Specialist: Dr. G. H. Harris;

CG-446-1 Condensed Guide to Hazardous Chemicals: Mr. S. Atallah (S. Stricoff, G. Coletta, E. Atkinson, R. McMahan);

CG-446-2 Hazardous Chemical Data: Dr. E. Atkinson (N. Levinson, M. Schofield, S. Sheth, S. Myers, V. Valeri, L. Tevekelian, R. Lawter, F. Granchelli, C. Riceman, W. Lyman, J. Stevens, R. McMahan);

CG-446-3 Hazard Assessment Handbook: Dr. A. Kalelkar (P.K. Phani Raj, J. Hagopian, D. Lee, S. Atallah);

Hazard Assessment Computer System (HACS): (G. Harris, P. K. Phani Raj, J. Hagopian, K. Wiig, and from ADL Systems, Inc., R. Potts and M. Sohn);

CG-446-4 Response Methods Handbook: Mr. J. L. Goodier (R. Horne, R. McMahan, A. Samsel);

Regional Contingency Plan Data Base: Mr. I. Avots (S. Stricoff, J. Hagopian, J. Blair, L. Sochrin);

CHRIS Training Systems: Mr. R. Abramson (S. Stricoff, J. Quick);

Chemical Hazards Response Information Systems for Multi-Modal Accidents (CHRISMA): Dr. G. Harris (J. Everett, V. Lewinson, D. Allan);

Survey Study to Select a Limited Number of Hazardous Materials to Define Amelioration Requirements: Mr. J. L. Goodier, Mr. D. Allan (W. Lyman, L. Nelson, L. Partridge, A. Kalkelar, J. Everett, G. Pollack); and

Inventory of Equipment and Agents for Responding to Marine Transportation Fires: Mr. S. Atallah (S. Stricoff, G. Pollack, C. Campbell).

We are also indebted to several consultants who made specific contributions and served to review drafts of CHRIS components. These include:

Professor Robert Reid, MIT, who estimated physical properties for CG-446-2, reviewed all physical property data, formulated specific hazard assessment models, contributed to the "amelioration" study and provided overall guidance and support in the development of CHRIS;

Professor John Peters, Harvard School of Public Health, who reviewed data on health hazards;

Professor Donald Harleman, MIT, who made major contributions to the formulation of water dispersion models; and

Dr. Daniel Schiff who helped define preliminary hardware requirements under the "amelioration" study.

Principal editors included W. Reehl, who performed all of the editing of CG-446-2, and D. Pierce.

1.0 EXECUTIVE SUMMARY

1.1 Introduction

The deployment of the Chemical Hazards Response Information System (CHRIS) represents a major and critical step in the U. S. Coast Guard's acquisition and development of the necessary capability to adequately respond to discharges of hazardous chemicals on water. It has been designed specifically to meet the emergency needs of field personnel, currently providing them with information on 400 hazardous chemicals, with methods of predicting hazards resulting from accidental discharges, and with procedures for selecting and implementing responses to accidental discharges. It is more comprehensive than any other system yet devised, but yet is arranged in a format which makes essential information readily obtainable during emergencies.

The development of CHRIS underscores the commitment of the U. S. Coast Guard to the reduction in risks of personal injury, property loss, and environmental damage presented by the water transport of hazardous chemicals. It forms a base from which methods and equipment may be developed to further improve the Coast Guard's capability to adequately control the transport of hazardous chemicals and to respond to accidents involving their discharge. Without CHRIS the Coast Guard would have to depend on a myriad of other data compilations, and on other agencies and personnel, to evaluate the hazards presented by accidental discharges, and upon contractors and consultants to assess whether responses to chemical discharges are adequate and sufficient.

1.2 The Development of CHRIS

CHRIS is composed of six basic elements, four manuals, a regional contingency plan data base, and a computerized hazard prediction system. It is designed to satisfy two basic modes of response; the first encompasses the very early stages of involvement by Coast Guard personnel. These early stages of response, lasting from a few minutes to several hours at most, will principally involve immediate on-scene Coast Guard personnel,

whose actions will be primarily limited to cautionary measures, rescue, first-aid treatment, observation, and reporting. The CHRIS manual specifically designed for this response mode is:

- CG-446-1 A Condensed Guide to Hazardous Chemicals.

The second or later response mode involves concerted efforts by Coast Guard personnel to minimize the threat and to take direct action to eliminate or correct the chemical discharge situation. These actions demand the involvement of technically trained personnel and detailed information on chemicals, their hazards, vulnerable resources, and response methods. The required information is contained in:

- CG-446-2 Hazardous Chemical Data,
- CG-446-3 Hazard Assessment Handbook,
- CG-446-4 Response Methods Handbook,
- Regional Contingency Plan Data Base.

In addition to the information provided to field personnel, a computerized system has been installed at Headquarters for use by expert personnel in predicting the extent of hazards from accidental discharges. This system is:

- Hazard Assessment Computer System (HACS).

In the course of the development of CHRIS, additional related work was also undertaken. Training courses were developed for use by MEP instructors at Yorktown and by Coast Guard Strike Teams. A special lecture set for describing CHRIS to non-users (e.g., interested public and industrial associations) has also been provided.

Special studies that have been completed include the development of a concept of a CHRIS-like system that would be applicable to chemical discharges from any mode of transportation, an identification and assessment of the factors that may influence the development of methods of ameliorating the hazardous effects of chemical discharges into water bodies, and an inventory of the equipment and agents that are currently available to the Coast Guard for responding to marine transportation fires.

1.3 Current and Future Work

Additional work relating to CHRIS that is either in progress or planned includes the addition of 500 chemical data sheets to CG-446-1 and CG-446-2, the development of additional hazard assessment models for HACS, improvements and refinements in HACS, and workbooks for USCG personnel to use for self training in the use of CHRIS. This work is planned for completion by mid-1976.

A study of the utilization of CHRIS by USCG personnel has also been initiated. This study, to take place over about one year, will note deficiencies, errors, and desired improvements in CHRIS. Information developed from this study will be used to revise CG-446-3 and CG-446-4; the revision is planned to take place during 1977.

1.4 Development Procedures

The development of the CHRIS components closely followed the specifications that were established in the preliminary design phase. During the first year of the development, frequent meetings (approximately two per month) were held with the Coast Guard technical monitor and his associates to review progress and to consider modifications and specific details of the CHRIS components. Decisions were reached as to refinements or changes in content. Drafts of all written material were reviewed by the Coast Guard and revised as requested prior to submittal of camera-ready copy. HACS was exercised by Coast Guard personnel and problems with its use are being resolved. The training documents and aids were tried out at the Yorktown training school and at the Gulf Area strike team offices prior to the submittal of the final training packages.

In the CHRIS development, the informational content was restricted to that which currently exists in the literature, with two exceptions; the first involved the use of well established procedures for estimating physical properties for many chemicals where these properties could not be found in the literature and where they were essential to the intended use of CHRIS. The second involved the development of a limited number of hazard assessment models that had not been reported previously.

In general, no special procedures nor information that related to special conditions to be found at individual ports or estuaries were incorporated in the hazard assessment and response handbooks nor was there a significant effort made to provide special assessment procedures for individual chemicals. The addition of information which would be more chemical and/or local specific in nature is a refinement to be considered for later modifications of CHRIS.

Also, the predictions of chemical hazards provided by the Hazard Assessment Handbook for discharges onto water tend to be conservative in that the worst conditions (greatest hazards) are predicted wherever there is uncertainty either in the predictive method or the meteorological, geographical, or hydrological conditions that might be present during an emergency.

1.5 Product of the CHRIS Development

The development of CHRIS has resulted in the completion of a total of some seventeen documents (and systems) in the form of manuals, handbooks, reports, computer systems, and training packages. These items are listed in the accompanying Table 1.

The development of CHRIS was initiated in May 1972 with the starting dates for individual CHRIS components and special studies extending from this date through June 1974. A schedule of the initiation and completion of major CHRIS components is given in Appendix A of this report.

TABLE 1

ITEMS DEVELOPED TO DATE UNDER THE CHRIS PROGRAM

- CG-446-1 A Condensed Guide to Chemical Hazards (CHRIS manual)
- CG-446-2 Hazardous Chemical Data (CHRIS manual)
  - Physical Properties Data File (computer file)
  - Identification of Data Gaps (report)
- CG-446-3 Hazard Assessment Handbook (CHRIS manual)
  - Assessment Models in Support of the Hazard Assessment Handbook (report)
- CG-446-4 Response Methods Handbook (CHRIS manual)
- HACS - Hazard Assessment Computer System (computer program)
  - Hazard Assessment Computer System - User Manual (manual)
- Regional Contingency Plan Data Base - Pilot Model (report)
- Regional Contingency Plan Data Base - Development Plan (report)
- CHRIS Users Workshop - An Instructor's Guide (manual and visual aids package)
- CHRIS Instruction Material (manual and visual aids package)
- CHRIS Non-User Presentation (visual aids package and narrative)
- CHRISMA - Chemical Hazards Response System for Multimodal Accidents (report)
- Inventory of Equipment and Agents for Responding to Marine Transportation Fires (report)
- A Survey Study to Select a Limited Number of Hazardous Materials in Order to Define Amelioration Requirements (report)

2.0 THE PRELIMINARY AND FINAL DESIGN OF CHRIS

2.1 General

This report summarizes the development of the major components of the Chemical Hazards Response Information System (CHRIS). It also describes specific studies that were conducted as part of the CHRIS program during the development phase. The reporting of the development of CHRIS is particularly appropriate at this time since the complete system has only recently been made available to Coast Guard users. The system will be carefully evaluated during the first year that it is in use, and the results of this utilization study will be reported on at a later date.

2.2 The Preliminary Design of CHRIS

At the start of the development phase, the basic objectives and concept of CHRIS as well as relatively detailed specifications of major components had been delineated as the result of a comprehensive study[(1)] completed by Arthur D. Little, Inc., in the early part of 1972. Primary guidelines for the concept and content of CHRIS that were originally established by the Coast Guard and which were further amplified and refined during the preliminary design of CHRIS included:

- The system is to support and be integrated with the National Response Center.
- The primary function of the system is to satisfy information needs during emergency response.
- Primary emphasis is to be placed on chemicals shipped in bulk rather than in packages.
- The system is designed to aid response to hazardous chemical discharges into navigable waters (not on land).
- The system is designed within the limitations of existing information and that which may reasonably be expected to become available within a period of five years.

- The system is designed on the basis of present response capabilities of the Coast Guard and on existing (or known) plans.
- The system is designed on the basis of existing and potential near-term modifications of federal regulations.
- The system is not designed to aid response during the restoration and law enforcement stages of a chemical discharge.
- The system is designed to provide chemical-specific information for at least 1,000 chemicals.

In the preliminary system design phase a survey was made of the potential users of the system and their needs. Existing data and information that might be required were also assessed. After a careful evaluation of the basic requirements and potential utilization of the system, including the current status and future outlook of response technology, it was concluded that user needs could be most effectively and beneficially met via a nonautomated, procedurely-oriented system. The proposed system encompassed the following five key reference sources designed principally for use by the On-Scene Coordinator and Coast Guard field personnel:

Manual No. 1 - A Condensed Guide to Chemical Hazards (CG-446-1);

Manual No. 2 - Hazardous Chemical Data (CG-446-2);

Manual No. 3 - Regional Contingency Plan Data Base (incorporated as part of the Regional Contingency Plans);

Manual No. 4 - Hazard Assessment Handbook (CG-446-3); and

Manual No. 5 - Response Methods Handbook (CG-446-4).

An automated component of the Hazard Assessment Handbook that would allow Headquarters specialists to exercise hazard assessment models was also recommended. It has subsequently been entitled Hazard Assessment Computer System (HACS).

In the preliminary design it was also emphasized that CHRIS would require an integrated organization and communications network for linking

together the On-Scene Coordinator, Regional Response Center, National Response Center, and recognized experts in the various fields of importance and for the overall management of the system after it has been implemented. The organization and communications aspects of CHRIS were not included in that part of the development carried out by Arthur D. Little, Inc., and hence, are not considered in this report.

2.3 The Results of the CHRIS Development

The work completed in this program consists of the development of four (CG-446-1, -2, -3, -4) of the five original manuals that were specified in the earlier study. The fifth manual, Regional Contingency Plan Data Base, was not developed by ADL. Instead, a pilot model of a Regional Contingency Plan Data Base for the State of Louisiana and a Regional Contingency Plan Data Base Development Plan were developed and furnished to the Coast Guard for use by USCG personnel in the development of data bases for each region. The HACS has been demonstrated, is being revised, and a Users Manual has been provided as a reference guide for the use of the system. A computer file of the physical properties of chemicals covered in CG-446-2 has been provided primarily for use as input to HACS. A separate report has been written on the analytical models that were employed in the derivation of the Hazard Assessment Handbook and which formed the base for the development of HACS.

Gaps in data needed for CG-446-2 have been identified in a separate report. Training courses were developed for use by MEP instructors at Yorktown and by the Coast Guard Strike Teams and a special lecture set was developed for describing CHRIS to untrained, non-Coast Guard personnel.

The special studies that have been completed are described within the body of the report.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 Major Conclusions and Recommendations

(1) The CHRIS, as developed, is a viable system providing the essential information for Coast Guard personnel to perform correct responses to hazardous chemical discharges on navigable waters.

The objectives and guidelines for the development of CHRIS that were established in the previous comprehensive study of user needs has been closely adhered to and great care has been taken to ensure the accuracy and utility of data and procedures.

(2) The CHRIS is the most complete, accurate, and comprehensive information source on hazardous chemicals, hazard assessment, and response to chemical discharges in existence.

- CG 446-1, A Condensed Guide to Hazardous Chemicals, provides the largest compilation of qualitative information on chemical hazards that is currently available for responding to chemical discharges on navigable waterways. It contains consistent and usable phrasing for those who must first respond to chemical discharges.
- CG 446-2, Hazardous Chemical Data, contains more complete and accurate data on hazardous chemicals necessary for responding to hazardous chemical discharges than any other compilation in existence. It contains a significant amount of physical property data that do not exist in any other reference source.
- CG 446-3, Hazard Assessment Handbook, is the only comprehensive handbook available for predicting the consequences of chemical discharges on water. Likewise, HACS is the only computerized system that covers nearly a full range of potential consequences of discharges into water.
- CG 446-4, Response Methods Handbook, is the only comprehensive handbook or textbook, for that matter, on methods of responding to chemical discharges on water.

(3) <u>CHRIS appears to be a major motivating force in upgrading the response capability of the Coast Guard</u>.

Attendance at training sessions, limited discussions with users, the increased numerical involvement of Coast Guard personnel, and interest that CHRIS appears to have generated among response specialists have served as indicators of a growing interest, knowledge, and motivation in response methods and technology.

(4) <u>There is an urgent need to develop the technology necessary for adequate response to hazardous chemical discharges</u>.

The lack of corrective response methods for the discharge of many chemicals severely limits the ability of Coast Guard personnel to be effective during an emergency situation. This limitation is most noticeable in the Response Methods Handbook (CG 446-4) and greatly reduces the effectiveness of CHRIS.

(5) <u>An effort should be made to increase the availability and utility of the Coast Guard's computational facilities</u>.

The present availability of computer time on the CDC 3300 computer system severely limits its usefulness during emergency response. The remote location of the plotter for HACS output and the substitution of line printer plots degrades the capability of CHRIS to provide the most useable graphical output of HACS.

(6) <u>The utilization of CHRIS during the first year trial period should be thoroughly evaluated and revisions should be made where necessary</u>.

It is reasonable to expect that the actual use of the system will reveal some deficiencies in presentation of information that will require corrective action. Provision should be made for revising any of the CHRIS components after its utilization in the field has been evaluated.

(7) <u>CHRIS can be a powerful tool in furnishing information and methods that can be used in support of activities other than, and in addition to, emergency response</u>. For example, consideration should be given to its application to the following areas:

- Contingency planning - It was strongly recommended in the preliminary design of CHRIS that incident-specific contingency plans be developed by the Coast Guard. This has been done for LNG/LPG shipments in specific ports. CHRIS has and can make significant contributions to contingency planning for other chemical shipments.
- Vulnerability modeling - CHRIS is currently being utilized to predict consequences of accidental discharges so as to make quantitative estimates of the risks of chemical shipments. Modifications or additions to CHRIS assessment methods that may be required to meet special needs of vulnerability modeling should be incorporated into CHRIS.
- Training - It has been demonstrated that training of response personnel in the use of CHRIS, in effect, trains them in response procedures at the same time. Full advantage of CHRIS to improve the training of personnel in response technology should be taken.

(8) <u>Current and foreseeable changes in the water transportation of hazardous chemicals and in the Coast Guard's responsibilities should be reviewed to determine their future impact on CHRIS</u>.

The implementation of spill prevention procedures, if effective, could significantly reduce the frequency with which CHRIS is applied and, in doing so, decrease the proficiency of the user. The passage of the Ports and Waterways Safety Act increases the Coast Guard's responsibilities to control and monitor hazardous chemical shipments and may eventually cause a major reduction in the number and size of accidental discharges. The effect of this new law on the usefulness and requirements for CHRIS information needs to be evaluated.

3.2 General Recommendations

Several conclusions and recommendations made as the result of the preliminary system development of CHRIS completed in May 1972 and which relate to Coast Guard's ability to respond to hazardous chemical spills are still valid and are repeated here for emphasis.

- The skill levels of all field personnel who deal with hazardous chemical spills need to be significantly improved.

  All such field personnel should receive intensive training in chemical technology and response procedures. Dangerous cargo officers should have formal, college-level chemical education and be trained in hazardous chemical safety. Occupational specialities in the area of chemical safety should be developed and/or improved so as to retain skilled Coast Guard personnel and to further enhance their capabilities; in this way a responsible and stable force may be created.

- The response to spills of hazardous chemicals has been and will continue to be for many years, highly dependent on the judgment of (experienced or inexperienced, as the case may be) field personnel.

  As hazard assessment and response technologies are significantly improved, greater reliance may be placed on documented, prescribed procedures and methods. The nature of a pollution incident is far too complex and little understood to permit detailed, quantitative analysis of alternative actions. Until the decision rules determining response actions have been defined, information system requirements cannot be known with great precision.

- Well-trained and readily available hazardous chemical specialists within the CHRIS organization should largely obviate the need for "experts" at the local (regional) level.

- An information system will not play an important role in identifying spilled hazardous chemicals in the foreseeable future until monitoring systems become far more sophisticated and widely deployed.

- A long-range (10-year) plan for identifying new information needs in spill response and means for satisfying them should be prepared by the Coast Guard.

  This plan should be periodically reviewed and modified at two-three year intervals. It is important that the Coast Guard maintain both medium- and long-term horizons to ensure that momentum is not dissipated and that Coast Guard capabilities continue to evolve in directions of greatest return.

- It is highly desirable to extend 33 CFR 124.14, Advance Notice of Arrival of Vessel Laden with Explosives or Certain Specified Dangerous Cargoes, to include all hazardous or potentially hazardous chemicals, regardless of quantity shipped.

  Furthermore, it would be desirable to require that all vessels, within 24 hours of arrival, report in accordance with the U. S. Coast Guard's Automated Merchant Vessel Report (AMVER) System and include the identity of any hazardous chemicals, the amount carried, and location of stowage on board the vessel. Since AMVER reporting is presently a voluntary matter, compliance can only be assured by an amendment to the regulations.

- Traffic management systems designed to provide control of vessel movement should be developed in the context of overall port safety rather than specifically for hazardous chemical shipments.

  The development of such systems will do far more to prevent hazardous chemical spills than they will to provide information for effective response to on-going incidents.

- A methodology needs to be devised for conducting retrospective spill analyses so that one may learn from past experience.

There is presently no formal method for extracting the essence of an incident in order to learn principles that may be applied during later spill situations.

4.0 CHRIS COMPONENTS

4.1 Condensed Guide to Chemical Hazards, CG-446-1

4.1.1 Scope and Content

The concept, content, and preliminary specifications for this manual were developed under the previous CHRIS contract (DOT-CG-03,223-A) and are described in an appendix to the final report.(1) The overall content of this manual was summarized as follows:

"This manual is to be a convenient source of chemical-related information that may be needed during the early stages of an incident involving the accidental release of a hazardous chemical. It will serve as a guide to port security personnel and others who may first arrive at the site of the incident and need readily available, easily understood, qualitative information on the hazardous nature of the chemical and situation confronted. It will assist these personnel in quickly determining responsible actions that must be taken immediately to safeguard life and property and reduce, insofar as may be possible, further contamination of the environment. The guide will contain precautionary advice on the chemical, physical, and biological hazards posed by the material and assist field personnel in performing an initial assessment of the threat as a prerequisite for determining subsequent actions.

"The manual will consist of a compilation of chemical data sheets having the format and general content illustrated in Figure 1. The data sheets will be filed alphabetically by the chemical name that is specified either in the Code of Federal Regulations (CFR) or other Government documentation. Reference to the chemical name will be aided by a coded designation for each chemical and by a thesaurus that will cross-reference synonyms (and trade names) with the official chemical name. In addition to the chemical data sheets and the thesaurus, the manual will contain explanatory material of the interpretation and use of its contents and a guide to the compatibility of chemicals."

The primary development of the manual was initiated during the fall of 1972 and the first edition containing data sheets for 400 chemicals was issued by the Coast Guard during 1974. An additional 400 chemical data sheets are being developed, and camera-ready copy will be furnished to the CoastGuard for printing and distribution.

CHEMICAL NAME CODE
(SYNONYM)
COLOR, ODOR, AND PHASE
PHYSICAL ACTION ON RELEASE

POISON (SYMBOL)

Fire	FIRE HAZARDS
Exposure	HEALTH HAZARDS AND FIRST AID
Spill or Leak	RESPONSE METHODS
Water Pollution	EFFECT ON MARINE AND WILDLIFE

DATA SHEET NO.
DATE

FIGURE 1 DATA SHEET LAYOUT

The development of this manual involved the refinement of the content requirements and of the data sheet format, the formulation of standard phrases for the data sheets and the selection of appropriate phrases for each of the 400 chemicals. The data compiled for CG-446-2, Hazardous Chemical Data, provided the basis for phrase selection. Introductory and other material were also developed. The manual was furnished to the Coast Guard in the form of camera-ready copy from which the first edition was printed.

A relatively detailed procedure of reviews by specialists and editing of the manual at various stages in development to insure consistency and accuracy was carefully followed.

An example of a data sheet appearing in the first edition of CG-446-1 is given in Figure 2. The specifications for this manual that were developed during the formulation of the CHRIS concept have been revised and are included in Appendix D-I of this report.

4.1.2 Development Procedures

The development of CG-446-1 involved the following work components:

4.1.2.1 Content

The content as specified during the concept stage was reexamined and refined. As the standard phrases for each data item were developed and reviewed the objectives and intent of each of the data items themselves were also examined. Frequent discussions were held with members of the manual working team, with reviewing specialists, and representatives of the U. S. Coast Guard. There resulted an improved and more explicitly defined list of data items deemed to best suit the objectives of the manual. These data items are listed and defined in the Explanation of Data Sheets section of CG-446-1. The development of introductory material, such as Notification, How to Use CG-446-1 and Where to Find Other Information followed this same general procedure. The Compatability Guide is merely a reproduction of the guide developed by the Coast Guard. The Thesaurus of Synonyms and Code Listing were developed as part of CG-446-2.

Figure 2

HYDROGEN SULFIDE	HDS

Common Synonyms			
Sulphuretted hydrogen	Liquefied compressed gas	Colorless	Rotten egg odor, but odorless at poisonous concentrations
	Sinks and boils in water. Poisonous, flammable, visible vapor cloud is produced.		

Avoid contact with gas. Keep people away.
Wear goggles and self-contained breathing apparatus.
Shut off ignition sources and call fire department.
Stop discharge if possible.
Evacuate area in case of large discharges.
Stay upwind and use water spray to "knock down" vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire	FLAMMABLE. Flashback along vapor trail may occur. May explode if ignited in an enclosed area. Wear goggles and self-contained breathing apparatus. Stop flow of gas if possible. Cool exposed containers and men effecting shutoff with water. Let fire burn.
 **Exposure**	CALL FOR MEDICAL AID. VAPOR POISONOUS IF INHALED. Irritating to eyes. Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen. IF IN EYES, hold eyelids open and flush with plenty of water.
Water Pollution	HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS. May be dangerous if it enters water intakes. Notify local health and wildlife officials. Notify operators of nearby water intakes.

CG 446–1

4.1.2.2 Development of Standard Phrases

In insuring consistency in the wording of the data sheets, a standardized list of phrases to be employed for each data item evolved. This list, along with explanatory material that provides a basis for the selection of phrases for any given chemical, is presented in Appendix DI Addendum (a). The listing of phrases was developed from an understanding of the overall objectives of the manual, from similar safety data compilations (e.g., References 2 and 3), through discussions with specialists, suggestions from the Manual Working Group and guidance from Coast Guard representatives.

The use of this phrasing requires that personnel knowledgeable in chemistry, fire technology, and health or medicine participate in the selection of phrases for each chemical and that they modify or temper the phrasing in specific cases where special precautions are required, the chemical has a unique or unusual characteristic, or where some additional explanation may be needed. A review of CG-446-1 data would indicate that there have been numerous modifications and additions of this type.

4.1.2.3 Format

The preliminary format for the data sheets was also reexamined and discussed with representatives of the Coast Guard. Refinements were made during the process of data gathering and several prototype data sheets were submitted to the Coast Guard for review and the final version was selected prior to the typing of camera-ready copy.

Several covers for the manual were also designed and furnished to the Coast Guard for review. The final version was specified by the project leader.

4.1.2.4 Procedures

The procedures employed in formulating material other than the data sheets involved direct use of some items that were developed for CG-446-2, and the modification of material that had either been cited or implied in the Preliminary Specifications.

The procedures employed in deriving data for each data sheet involved personnel with training in appropriate technical areas. For each chemical, data that was gathered, processed, and reviewed for CG-446-2 were used by CG-446-1 personnel to select appropriate phrases for each data item. The basis for the selection of phrases for each data item is essentially that given in the Explanation of Data Sheets [reproduced in Appendix DI, Addendum (b)].

The selected phrases for each data item for each chemical were then retyped and furnished to reviewers to check validity and accuracy.

After review by specialists, the data for each chemical were furnished to a contractor for final typing. The camera-ready copy was edited by professional editors, corrected, and the final copy sent to the Coast Guard.

At the conclusion of the development of the data sheets for the first 400 chemicals, it was realized that a considerable saving in editorial and first draft typing time could be achieved if phrases were standardized and computerized. Upon authorization to proceed on the development of data sheets for an additional 500 chemicals, the phrases utilized in CG-446-1 were reviewed, standardized, numerically referenced and stored on a computer. After completion of the literature search for the 500 additional chemicals, the reviewers simply circled or checked the appropriate numbers of the pertinent descriptive response and warning phrases to be used for each chemical on a pre-prepared form. Numbers were then punched on computer cards and a printout produced in duplicate for each chemical. In format, the printouts resembled the final form of CG-446-1 pages. One copy of the printout was then edited and reviewed by the technical reviewers and final changes made to the second copy which was sent for final typing.

4.1.2.5 Data Review

The selection of standard phrases using CG-446-2 was carried out by engineering personnel who were trained in fire protection, toxicity, and industrial hygiene. The fire protection data were reviewed by a

chemical engineer with an advanced degree and some 10 to 15 years' experience in fire research and engineering. Exposure data were reviewed by a chemical engineer with an advanced degree with 15 to 20 years' experience in chemical plant design, operations, and hazard analysis.

The CG-446-1 data were also reviewed in detail by the Manual 2 leader to check for inconsistencies between the data for the two manuals. A secondary review was made to verify or evaluate the consistency of data with data compilations of the Manufacturing Chemists' Association and with that of CG-338.

4.1.3 Considerations Involved in Development of CG-446-1

A number of questions arose as to format, definition of terms, phrasing, the need for additional information as well as other pertinent issues, during the early stages of development. These questions or issues were discussed during frequent CHRIS review meetings attended by those responsible for the development of each major CHRIS component, the Coast Guard project leader, and others responsible for CHRIS. The questions were resolved, and the more significant issues were noted in the reports of these meetings. Typical issues that were resolved during the development of CG-446-1 include the following:

- It was suggested that a preface be added to CG-446-1 to describe the intended use and content of CHRIS and the role that CG-446-1 plays in applying the system. It was concluded that the preface would not be added because its use was not dependent on other components of CHRIS, nor did the use of other components depend to any major degree on the availability and use of CG-446-1. In addition, some of the information on CHRIS that could have been put into a preface has been included in the Letter of Promulgation.
- It was suggested that the Letter of Promulgation contain a warning to the effect that, as with all new systems, errors may be found in the manual during the early stages of its implementation. Even though all reasonable precautions have been taken in checking and editing the

data, there may be a few undiscovered errors which might result in wrong response if the data were used as reported. The Coast Guard chose not to add this warning, presumably because it might have detracted from the effective use of the system.

- A section entitled "Information Needs for CG-446-3" was added because this is primary input data that may first become available to the individual that initially responds to an emergency. It was concluded that the accuracy of the information that may be required for quick and effective hazard assessment would be enhanced by providing written instructions as to what specific information may be needed.

- The "Explanation of Data Sheets" is more detailed than originally planned. It was decided that <u>every</u> category of data should be covered to alleviate misunderstanding of the intent of each data item.

- Criteria for establishing whether a specific chemical would be put in the poisonous category were particularly difficult to formulate. The criteria that were finally chosen were based on the desire to make the definition conform reasonably well to that perceived to have been used in applying this term to the Code of Federal Regulations.

- Boiling points and freezing points are listed for those chemicals whose physical state may change within the temperature ranges that might be experienced during transport; that is, those chemicals whose boiling or freezing points are near ambient.

- A number of changes in data sheet format were made for reasons of consistency and to highlight the more important hazards and responses. The logic employed should become reasonably evident from an examination of the illustration given on page 5-2 of CG-446-1.

- An index of recognition codes was added as a necessary feature. The absence of an index could make it difficult for the user to find the data sheet for the chemical of interest since an alphabetical ordering of the recognition codes would not be the same as that for the chemical names. The problem of locating a specific chemical data sheet using the recognition code without the aid of an index becomes more difficult as the number of chemicals in the manual is increased.

4.1.4 Conclusions and Recommendations

4.1.4.1 Conclusions

(1) The Condensed Guide to Hazardous Chemicals is the largest compilation of qualitative information on hazardous chemicals in existence that is intended for responses to discharges on navigable waters.

(2) It has the most consistent and best phrasing of hazards and response actions compared to any other existing compilation.

(3) Prior evaluations of user needs serve to insure that it will be, by far, the most valuable source of information to Coast Guard or other personnel that are generally the first to respond to hazardous chemical discharges.

4.1.4.2 Recommendations

(1) It is highly recommended that provisions be made to revise and correct the manual after it has been used by personnel in the field for approximately one year and after its utility has been carefully evaluated.

(2) In revising the manual, consideration should be given to the following items.

- The reintroduction of a preface or its equivalent which would contain a statement of the purpose of the manual, a description of its content, an introduction to the problems faced in emergency responses to chemical discharges and a discussion as to how the manual relates to the rest of CHRIS.

- An expansion of the list of synonyms to include foreign terms. This change could enhance quick identification of chemicals shipped on foreign vessels.

- The identification of poisonous gases that can result from chemicals reacting with water, metals, or air, and an indication of the respective first aid measures that should be taken.

- The addition of information that would distinguish between small and large fires in recommending preferred extinguishing agents.

- An improvement in the description terms used in the water pollution section of the data sheets. Very little distinction is made, for example, between birds and marine life, nor are distinctions made between different kinds of birds.

- Improvements in consistency of phrasing. The development of standard phrasing for CG-446-1 evolved as initial data sheets were made up so that the phrasing of some of the earlier sheets differs in relatively minor aspects with those that were developed later on.

4.2 Hazardous Chemical Data, CG-446-2

4.2.1 Scope and Content

The overall content of this manual was described in an appendix to the final report[1] on the development of the CHRIS concept under contract (DOT-CG-03,223-A). The content of this manual was summarized as follows:

"This manual is to contain chemical-specific information in sufficient detail to assist trained field personnel and hazardous chemical specialists in monitoring, guiding and managing responses to accidental releases. In contrast to Manual No. 1 that is a source of qualitative, easily understood information for use by less well trained personnel during the early stage of response, this manual will contain all of the existing, pertinent, and detailed information on each chemical. This data will encompass physical and chemical properties; flammability, health and pollution hazards; industrial information; and response information specific to each chemical.

"The manual will consist of a compilation of data sheets with several pages devoted to each chemical. The sets of data sheets will be filed alphabetically by the chemical name that is specified either in the Code of Federal Regulations (CFR) or other Government documentation. Reference to the chemical name will be aided by a coded designation for each chemical and by a thesaurus that will cross-reference synonyms (and trade names) with the official chemical name. In addition to the chemical data sheets and the thesaurus, the manual will contain explanatory and supplementary material that will be necessary and helpful to the user, and a guide to the compatibility of chemicals."

It was planned that the manual would be printed in two versions; one containing a complete set of data for each chemical for the hazardous chemical specialists, and the other containing only those items deemed useful by trained field personnel. As the development of this manual progressed and the list of specific data items were modified and redefined, it was found that <u>all</u> of the material could be of use to field personnel as well as Headquarters specialists. Hence, it was decided that only one version of the manual would be printed.

Specific data items cited in CG-446-2 were also stored in the Coast Guard computer for use as input to the Hazard Assessment Computer System (HACS). Some of these stored data were used to make computer plots of those physical properties that were recorded as a function of temperature for insertion in the manual. The development of the computer file and the printout of data (plots) for CG-446-2 camera-ready copy was considered to be a part of the development of this manual, rather than the development of HACS.

The development of this manual involved the refinement of the content requirements, the collection of data, data reviews and processing, and the printing of camera-ready copy. Much of the refinement of data items was affected by frequent reviews of the needs of the Hazard Assessment Handbook, CG-446-3, for physical property data and for the information requirements of the Condensed Guide to Chemical Hazards, CG-446-1.

Detailed procedures for recording, storing, processing, reviewing, and editing the data were established and were carefully followed. Preliminary specifications for this manual were written under the previous report and appear in the appendix to that report. Because the published manual contains definitions of data items under Explanation of Terms and much of the remainder of the information content is self-explanatory, we have not written revised specifications. Rather, we have included specific instructions or information in this final report for those cases where specific procedures were established and where they have not been documented elsewhere. Publication specifications are given in Appendix D-II.

4.2.2 Development Procedures

4.2.2.1 Content

The list of 400 chemicals that are included in the manual was compiled and submitted to the project leader for approval. The list of chemicals includes all of the 284 materials listed in 46CFR151, Cargoes Regulated by Subchapter O (Table 151.01-10b) and Cargoes Regulated by Subchapter D (Table 151.01.10d). The remainder of the chemicals was selected from a preliminary list of Hazardous Polluting Substances that has been prepared by the EPA. Selection of chemicals from this list was based on experienced judgment as to the chemicals where Manual No. 2 data may be most important. This selection was made by the consensus of

several knowledgeable professionals on the basis of relative magnitude of the chemical being shipped and the extent to which the chemical may be transported and its hazard severity. The selected list was reviewed, discussed and approved by the Coast Guard.

The subsequent list of 500 chemicals that are to be included in CHRIS as part of the Phase II and III efforts was provided by the Coast Guard. After a preliminary survey of manufacturers' information by ADL personnel for each chemical, some chemicals were eliminated because of lack of commercial interest (little or none being currently produced), and additional chemicals were added to the list to substitute for the discards (again upon Coast Guard review and approval).

- Introductory Material: The introductory, or ancillary material that has been placed in CG-446-2 followed the outline given in the preliminary specifications. Details of content and presentation were reviewed relative to need and utility and modified as this manual and other components of CHRIS were developed.

- Data Sheets: Data items cited in the preliminary specifications were reviewed during the initial development phases as to their applicability to the overall CHRIS needs and modified to insure that only primary and useful data would be provided. This review and evaluation involved specialists at ADL and several meetings and discussions with Coast Guard personnel. Some data items, however, such as Item 1, Response Procedures, were established prior to the development of other CHRIS components (in this case, CG-446-4, Response Methods Handbook). Hence, some of the present phrasing could be refined to conform better with that employed in other CHRIS components.

The phrasing of material on exposure hazards and response exposure followed the general practice employed in other data bases and first aid manuals since the user would be expected to be generally familiar with these terms. The section on fire hazards and response also employed common terminology. Although formal procedures specifying standard phrasing were not developed, uniformity and consistency were maintained by generally utilizing the

same specialists, reviewers, and editors for each type of category of information throughout the data review process.

4.2.2.2 Data Collection and Reviews

Data sources were selected and employed in accordance with the approach outlined in the final report on the CHRIS concept. As data were collected and evaluated, some sources were added and others deleted in an attempt to acquire the most valid data and to collect as much of the required data as available. The review and modification of sources were affected by the manual leaders and data review specialists. The primary list of data sources that was employed in data collection is given in CG-446-2 and cited in Appendix B-IV of this report.

A master file with data folders for each chemical was developed and maintained. For each data item, for each chemical, the source of the data and the initials of the person who collected the data were noted. The manual leader reviewed the source, quantitative values, and qualitative information as a check on validity, periodically, during the data collection phase.

Most personnel that collected data had at least a B.S. degree in chemistry and all of them had training and experience in literature search. Each searcher was assigned a category of data that best suited his or her training and experience.

As the data collection progressed, it was determined that many physical property data items needed for use in CG-446-3, Hazard Assessment Handbook were not found in the primary data sources, but could be estimated to the desired accuracy using well developed and established techniques. The methodology that was employed is that given in Reference 4. In many instances unpublished but more recent and accurate methods were employed. The selection of method and the actual estimation were carried out by a specialist in the development of methodology for estimating physical properties. This has resulted in a compilation of specialized physical property data that are unusually complete, and it is expected to add greatly to the utility of CHRIS. A formalized presentation of the methods employed and the basis for their selection is beyond the scope of this contract. Methods employed in the development of fire hazard data, however, are presented in Appendix B-V.

After each category of data was collected for the 400 chemicals, it was reviewed by a specialist selected for his knowledge and experience with the technical subject involved. Resumes of all review personnel were submitted to the Coast Guard for approval prior to performing specified review tasks. Each reviewer has been requested to certify in writing that he has examined specified data and found them to be valid and correct.

After the data reviews were completed, the manual leader for CG-446-1 made a check of each item that had been reviewed to insure completeness. The master file of data was then turned over to a professional editor and chemical engineer who prepared the data for transmittal to the typesetter.

As camera-ready data sheets were completed by the typesetter, they were proofed by the editor and returned for correction. Corrected data sheets were again proofed by the editor and finally were inspected by the CG-446-1 manual leader. When the camera-ready copy for all 400 data sheets was completed, a photocopy was made and retained as insurance against loss of the master copy. The data sheets, along with introductory and ancillary material and camera-ready copy of the manual covers, were forwarded to the Coast Guard for printing.

As in the case of CG-446-1 a Manual Working Group, composed of representatives of the chemical industry, was formed and met to review the content and objectives of the data sheets. Data were forwarded to selected representatives who had large proprietary data bases within their own companies to review the material for completeness and comment.

4.2.2.3 Special Data Items

As part of the CHRIS program, physical property data required as input for the hazard assessment computer system (HACS) was transcribed from the data sheets and placed in a computer file. The content and details of this file are described in the HACS Users Manual furnished to the Coast Guard as part of the development of HACS. This physical properties computer file was used to provide computer plots of those data items where the physical property is given as a function of temperature. These computer

plots were pasted onto 8-1/2 x 11 sheets and furnished to the Coast Guard as part of the camera-ready copy data sheets for CG-446-2. The procedures employed in making up the computer plots are described in Appendix B-I of this final report.

Two other special data sheet items involved the formulation of specialized codes for recognition of chemicals and for designating the hazard assessment procedures to be employed for each chemical when using CG-446-3, Hazard Assessment Handbook. The procedures for assigning code designations are included in Appendices B-II and B-III of this final report.

4.2.2.4 Data Accuracy

Most of the quantitative data have been cited to no more than three significant figures. The accuracy attained depended upon the type of data and the methods employed in its derivation. No attempt was made to cite the known or estimated accuracy of the data in CHRIS for this is not an issue. The primary use of the data involves input to hazard assessment computations either through the application of CG-446-3, Hazard Assessment Handbook, or HACS. The input data need only to be as accurate as the hazard assessment procedures demand. Since there is substantial uncertainty in hazard assessment, primarily because of the lack of information on the exact quantity discharged, but also because of limitations in assessment models and in knowledge of the exact effects of each chemical, the input data needs to be accurate only to within a factor of two or three in most cases. Nevertheless, the accuracy of the data has generally been maintained at the level that it has been found in the literature, i.e., up to at least three significant figures.

4.2.2.5 Data Gaps

Upon completion of the data gathering and reviews, data that were needed for CHRIS but not found in the literature and not amenable to estimation methods were noted. These data gaps were compiled in the form of a master matrix with the relative importance of each item of missing data noted. A report that describes this process and which contains the matrix of data gaps was furnished to the Coast Guard.

4.2.2.6 Format and Publication Specifications

The data sheet format described in the preliminary specifications was modified and refined as the data items were altered and data collected. The final format resulted from several discussions with Coast Guard personnel and ADL specialists considering priority of data items, uniformity of presentation and other factors deemed important to the user.

When the final format was approved by the Coast Guard, new publication specifications were written.

These specifications are included as an Appendix to this final report. In examining these publication specifications, it will be noted that the data for each chemical was to take up both sides of three 8-1/2 x 11 sheets (one side of one sheet being a data sheet from CG-446-1). To reduce bulk and to make the manual more manageable, the Coast Guard subsequently decided that as part of the printing process the camera-ready copy would be reduced in size so that all of the data for each chemical would be contained on a single sheet. This is the form in which CG-446-2 has been published.

4.2.3 Considerations Involved in Development of CG-446-2

As with CG-446-1 many issues dealing with content and format were resolved during frequent CHRIS review meetings with Coast Guard representatives and the CHRIS project team. The final resolution of many of the content issues should be evident to the reader by an examination of the "Explanation of Terms" and of the data sheets themselves. Some issues of apparently minor significance were not recorded and some have not been recalled during the writing of this report. Those topics involving issues and procedures that have been recalled and may be of interest during future revisions of this handbook are discussed as follows:

- Selected properties of fresh water, sea water, ice, and air were added to this handbook because of the needs of the Hazard Assessment Handbook and because it is perceived that future users may have need of data on the environment into which hazard chemicals are discharged.

- The Coast Guard provided authorization to add chemicals to the Compatability Guide that was furnished by the Coast Guard. The selection of a reactivity group for each of these chemicals may not have involved the same procedures employed in deriving the basic Guide. It did appear desirable, however, to provide some indication of compatability characteristics for these chemicals rather than to omit this information and depend upon it being added at a later date after the Coast Guard had revised the basic Compatability Guide.

- The data item Response to Discharge required that simple, concise guidance be provided in the data sheets. It was originally planned that both cautionary and corrective responses that were developed for the Response Methods Handbook would be cited. However, because of scheduling, the list of cautionary and corrective responses had not been developed at the time these data items were needed for Hazardous Chemical Data sheets. Accordingly, special phrasing for Response to Discharge was developed for the data sheets. Consideration should be given when CG-446-2 is revised to replacing the present phrases with the applicable methods that have now been developed for the Response Methods Handbook.

- The list of data items that was given in the preliminary specifications was reevaluated in terms of CHRIS needs. This reevaluation included data requirements for CG-446-3 and HACS and the relative value of specific water pollution items. It was concluded that several of the physical properties that had been listed would have no application in the hazard assessment models being formulated, and hence would be eliminated. Several of the water pollution data items were deleted because they concerned long-term effects which were outside the scope of CHRIS. MCA-Transportation Emergency Guides were deleted because this system had not been and might never be implemented. The ratio of specific heats was retained upon the specific request of the Coast Guard. Those data items that were eliminated include:

Critical volume;
Acentric factor;
Coefficient of thermal expansion;
Specific gravity of the vapor;
Viscosity of vapor as a function of temperature;
Latent heat of fusion;
Effect on water treatment processes;
Fouling agent;
Field detection limit; and
MCA - Transportation Emergency Guides.

- Preliminary specifications for CG-446-2 indicated that two sets of units would be used in reporting physical property data. One set would be the internationally approved SI units and the other would not be a "standard" set but involve the units that occur most commonly in engineering practice. Because of difficulties in making decisions as to the most commonly used units, both English and cgs units were included in addition to the SI standard whenever it appeared that this procedure might enhance the utility of the data sheets.

- Consideration was given to incorporating the equations from which the graphs of temperature-dependent physical properties were derived - along with the graphs on each data sheet. Consideration was also given to adding a single value (for ambient conditions) for each of the temperature-dependent properties. Neither of these additions appeared to be justified, however. The equations would not increase the user's facility to obtain desired values and there might be a tendency for him to use the equations to derive values beyond the range of temperatures for which they are valid. Single-point values would, in effect, add another data item requiring additional effort without sufficient compensatory advantages.

  The equations employed in both estimating and checking physical property data are on record in the master data files.

- The temperature range over which temperature-dependent physical properties were plotted depended upon the characteristics for each chemical and the availability of data. In general, for those chemicals whose normal boiling points are higher than 32°F, the temperature range for all items, except Ideal Heat Capacity, was from -10 to +130°F or some smaller range depending on the availability of data. The Ideal Heat Capacity was generally extended to 600°F. Where the literature only provided a single value, it is shown as a straight line on the plots and the temperature range over which the line extended was derived by judgment as to the range over which this value would be expected to remain relatively constant.

  For some 24 materials whose normal boiling points are equal to or less than 32°F, the temperature range for the seven liquid and saturated vapor properties extended from the normal boiling point minus 50°F to slightly above the normal boiling point. Again, the Ideal Heat Capacity was extended to 600°F and the actual temperature ranges employed were influenced by the availability of data.

- The inclusion of a specific literature citation for each data element on each data sheet was considered. After discussions with the project leader it was concluded that the use of a reference key or some other system to allow the user to look up the original reference would not be of sufficient utility to warrant the additional effort required to transfer this information to the data sheets. Instead, it was agreed that a careful record of the source of each data item would be kept in the permanent master data files. A list of the data sources that was employed is given in an addendum to this chapter of the final report.

- The review of data by expert reviewers to insure the adequacy and reliability of data followed the general procedures below:

  a. Health Hazards - the applicable experience and knowledge applied by the reviewer is given in an addendum to this section of the final report.

b. Flammability - the basis for estimating and checking values and quantitative guidance is given in an addendum to this section of the final report.

c. Water Pollution - the review of these data primarily depended upon the experience and knowledge of the individuals selected to review this material.

d. Physical Property Data - each and every item of data was checked. Some values were verified by inspection; others were verified by estimating properties from fundamental principles.

e. All Other Data - the remaining data items were checked by the person responsible for developing this handbook.

4.2.4 Conclusions and Recommendations

4.2.4.1 Conclusions

(1) The Hazardous Chemical Data Handbook is the most thorough, accurate, and complete set of data that is available for assessing hazards and formulating responses to chemical discharges. The best reference sources were used to compile the data and the parallel development of the Hazard Assessment and Response Methods Handbooks helped to insure that all pertinent data items were included. Special procedures were followed to insure verification and accuracy of the data.

(2) With adequate maintenance and updating this data compilation should, for many years, serve as a major national resource for engineers, scientists and other specialists who have need for hazardous chemical data. It is our understanding, for example, that it is already being used in support of work in the area of occupational safety and health.

4.2.4.2 Recommendations

(1) It is highly recommended that this handbook be revised after completion of the study on the utilization of CHRIS. Consideration should be given to issuing a second edition containing revisions and additions derived as the result of:

- An evaluation of the use of the handbook during the first year that it is available to Coast Guard personnel;

- Suggestions by personnel responsible for compiling the handbook; and

- Changes in reference material such as that contained in the Code of Federal Regulations and NAS Hazard Ratings for Bulk Water Shipments.

If most of these revisions were to be made almost every data sheet would have to be modified in one way or another.

(2) The following is a preliminary list of suggested revisions:

- There are at least 50 errors of commission and omission in existing data sheets that were not found until after publication. These errors need to be corrected and are on record in data files.

- Many chemicals that are no longer items of commerce should be deleted from the handbook.

- Data should be changed to conform to recent revisions in the Code of Federal Regulations. For example, CFR changes have been made in the definition of flammable materials and these changes should be reflected in labels and response to discharge. Also, OSHA has issued extensive regulations for carcinogenic chemicals at least four of which are contained in CHRIS.

- A new hazard rating system[5] developed by the National Academy of Sciences Advisory Committee should be substituted for the ratings that are now contained in CG-446-2 as soon as the revised system is published.

- An attempt should be made to improve on aquatic toxicity data to provide more information on accute effects and to broaden the coverage of this data item to include, for example, shellfish and aqueous plant life.

- The Compatability Guide needs to be modified to conform to the new guide as published in Navigational and Vessel Inspection Circular No. 4-75.
- Data reported for Storage Temperature, Inert Atmosphere, and Venting should either be removed for those chemicals where this information is not contained in the Code of Federal Regulations or the fact that the data is not supported by the CFR should be so noted.
- The size of print employed in the handbook as it is currently published should be reconsidered. It may be found that significant errors in its use may result from the difficulties associated with quick reading of small print.

4.3 Hazard Assessment Handbook, CG-446-3

4.3.1 Scope, Content and Status

The concept, content and preliminary specifications for this manual were developed under the previous CHRIS contract (DOT-CG-03,223-A) and are described in an appendix to the final report[1]. The overall content of this manual was summarized as follows:

"The Hazard Assessment Handbook provides trained field personnel and other hazardous material specialists with methods and procedures for estimating the magnitude and location of the threat presented by the potential or actual release of a hazardous chemical. It provides a sound approach to the selection and use of quantitative methods for predicting the many physical processes that may occur upon the release of a wide variety of hazardous chemicals. It includes procedures for predicting the rate of release of the chemical from its container, the movement and dispersal of the chemical in water and/or in air, the thermal radiation from fires and the area over which the resulting toxic, thermal and explosive effects may threaten vulnerable resources. This manual should play a major role in supporting the selection and employment of adequate and appropriate responses."

The manual will also serve to provide fundamental analytical tools for nonemergency-related activities concerned with the prevention and control of hazards presented by water transport of chemicals.

The methods and procedures to be incorporated in the hazard assessment portion of CHRIS are presented in two forms. The first includes relatively detailed computational procedures for use by highly trained specialists. These procedures programmed for machine computation constitute the Hazard Assessment Computer System. The Hazard Assessment Computer System is described elsewhere in this report. The second form, the manual, consists of a series of tables, charts, nomographs, and other graphic aids which may be employed by field personnel to assess quickly the threat during an emergency. The procedures employed in the field version of the manual are necessarily relatively simple and limited in

extent to facilitate their use by less experienced personnel. This chapter is concerned with the manual approach to hazard assessment and describes the approach and some of the problems associated with the development of the Hazard Assessment Handbook.

The primary development of the manual was initiated during the fall of 1972 and the first edition containing the completed assessment procedures was issued by the U. S. Coast Guard in 1974. The Table of Contents for the Hazard Assessment Handbook is provided in Table 2. The Hazard Assessment Handbook is currently being utilized in the field and the first revision incorporating suggestions from field personnel based on their experience in manual utilization is planned for 1976. During this revision certain models and methods will be replaced by newer, more accurate methods that have recently been developed. Brief specifications for the present or existing version of CG-446-3 are given in Appendix D-III.

4.3.2 Development Procedures

The development of CG-446-3 involved the following major work components:

4.3.2.1 Content Specification

The content as specified during the concept stage was reexamined and refined. Detailed discussions were held with USCG personnel at Headquarters and at various COTP offices to insure that the content specification were sufficiently complete that a workable product would result. The basic content of the manual consists of four major parts. These parts are:

1. Method of determination of the on-scene information needs by acquiring information pertinent to a spill situation;
2. Selection of appropriate calculational procedures;
3. Approach to actual hazard assessment; and
4. Tables and charts in support of the assessment models.

In addition to specifying the contents of these four major parts of the manual, much effort was spent in ensuring that the other CHRIS manuals,

TABLE 2

HAZARD ASSESSMENT HANDBOOK

		page
1.0	CHRIS MANUALS	1
	1.1 PURPOSE AND SCOPE	1
	1.2 A CONDENSED GUIDE TO CHEMICAL HAZARDS	1
	1.3 HAZARDOUS CHEMICAL DATA	2
	1.4 HAZARD-ASSESSMENT HANDBOOK	2
	1.5 RESPONSE METHODS HANDBOOK	2
	1.6 DATA BASE FOR REGIONAL CONTINGENCY PLAN	2
	1.7 HAZARD-ASSESSMENT COMPUTER SYSTEM (HACS)	3
2.0	OVERALL APPROACH	4
	2.1 INTRODUCTION	4
	2.2 APPROACH	4
	2.3 HAZARD ASSESSMENT	8
3.0	INFORMATION NEEDS	9
	3.1 ORGANIZATION OF INFORMATION NEEDS	9
	3.2 PRIMARY LIST OF QUESTIONS	9
	3.3 SECONDARY LIST OF QUESTIONS	10
	3.4 LIST OF INFORMATION SOURCES	11
	3.5 DETAILED DESCRIPTIONS OF INFORMATION SOURCES	15
4.0	SELECTION OF CALCULATION PROCEDURES	45
	4.1 HAZARD-ASSESSMENT AND CALCULATION CODES	45
	4.2 CHOICE OF CALCULATION PROCEDURE	45
	4.3 CALCULATION TABLES AND FIGURES	46
5.0	HAZARD ASSESSMENT	47
6.0	FIGURES AND TABLES	106
7.0	ACCURACY OF THE HAZARD ASSESSMENT	199
8.0	USE OF THE HAZARD-ASSESSMENT COMPUTER SYSTEM (HACS)	200
APPENDIX A - USEFUL CONVERSION FACTORS		201
APPENDIX B - EXPLANATION OF TERMS		204

particularly the Hazardous Chemical Data Manual (CG-446-2), were compatible and fully responsive to the impact requirements of the Hazard Assessment Manual.

4.3.2.2 Approach to Information Needs

In the event of a spill or discharge of a hazardous chemical into or onto a body of water, Coast Guard personnel will need certain on-scene information to assess the hazard presented by the spill and determine the appropriate response. This information was found to be of two types: (1) that which is absolutely essential for even the most basic assessment of the hazard potential; and (2) that which will permit a more refined and accurate assessment if time permits. It was judged that the necessary information can best be obtained by answering a series of questions.

The list of questions which must be answered before any kind of hazard assessment can be contemplated was designated the "primary list of questions." Examples of primary questions are: what is the identity of the chemical being discharged? What is the rate of discharge or the total quantity involved? A complete list of questions which must be answered prior to hazard assessment was developed. Also developed was a "secondary list of questions" which should be answered (if time permits), and which would enable the CHRIS specialist at headquarters to perform a more detailed and refined hazard assessment using HACS. Suggested sources for answering the primary and secondary list of questions were also developed and presented in the manual.

The primary and secondary lists of questions are repeated in the Condensed Guide to Chemical Hazards, CG-446-1, which would be carried to the accident scene by on-scene personnel.

4.3.2.3 Selection of Calculation Procedures

Once the chemical being discharged has been identified, the hazard presented can readily be assessed, provided one could determine its interaction with water. To attempt to treat each and every chemical individually in describing its interactions with water would lead to a very large and unwieldy document. It was judged that a more logical

approach is to generalize the various chemical-water interactions that can occur and represent them in the form of a hazard-assessment tree. This tree, which is to be used with this handbook, is shown in Figure 3. If one knows the properties of the chemical, he can follow the appropriate vertical path(s) in the tree and determine which calculation procedures he must use to assess the hazards presented by the chemical. Both the hazard-assessment path and the needed physical properties are provided by CG-446-2, Hazardous Chemical Data.

The first box (beneath ACCIDENT) in Figure 3 is designated by the letter A and represents a quantitative description of the discharge; e.g., the chemical, its rate of flow or total quantity discharged, the state of the discharged chemical, and significant parameters, such as temperature and pressure. Methods of identifying the chemical, quantity in transport, and rate of release constitute on-scene information needs discussed earlier. Once the chemical has been identified, its physical properties can be obtained from CG-446-2, Hazardous Chemical Data.

Depending on the state of the released chemical (gas, liquid, solid, or mixture), it can be said to belong to one or more of the vertical paths shown in Figure 3.

- Gases
- Liquids
    - Non-reacting with water
        - Boiling point below ambient temperature of water
        - Boiling point above ambient temperature of water
    - Reactive with water
    - Self-reacting (polymerization, decomposition, etc.)
- Solids
    - Soluble
    - Insoluble
    - Reactive

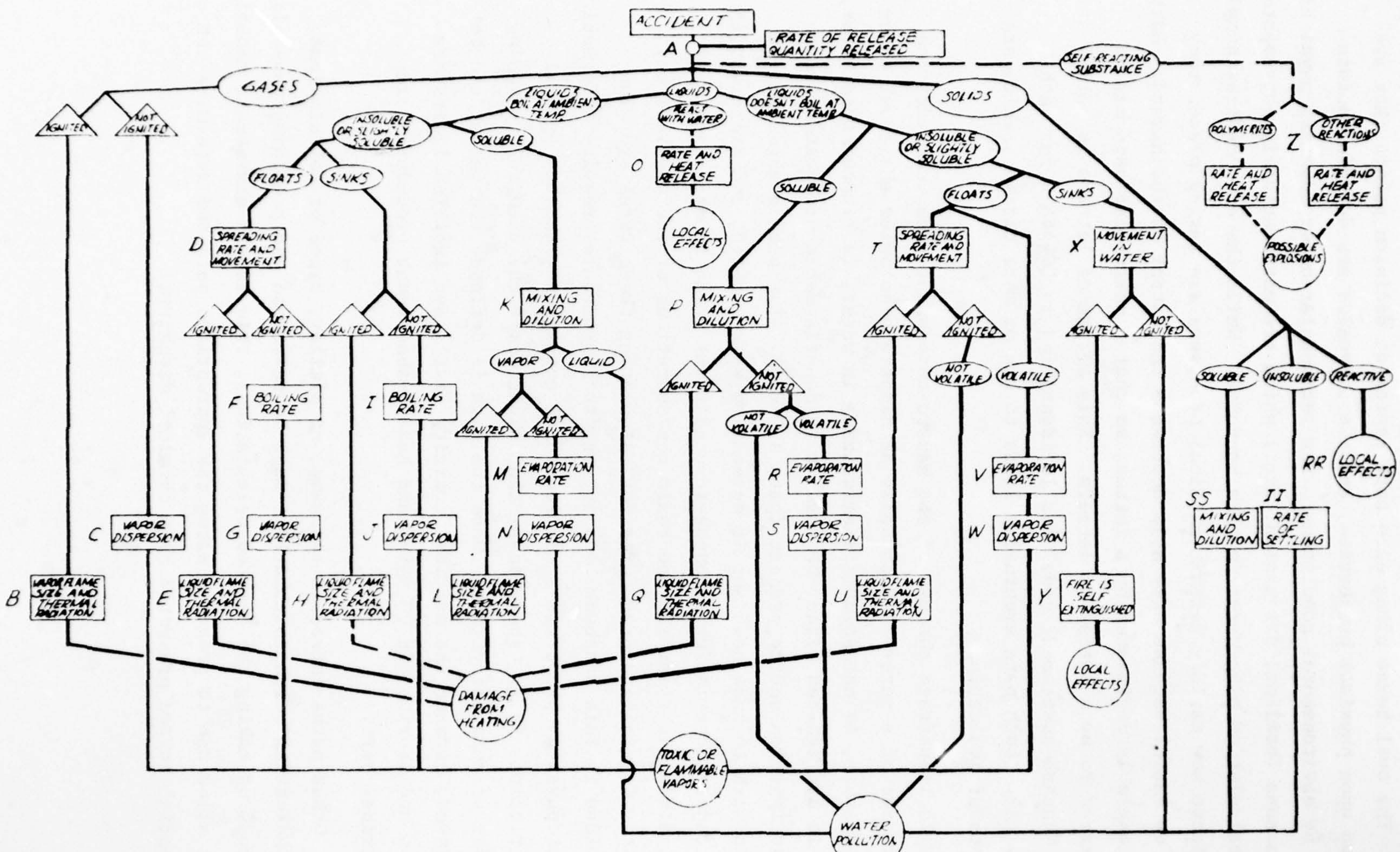


FIGURE 3 HAZARD ASSESSMENT TREE: (Events Chart)

The oval boxes along each path represent decision points that are based upon physical properties, and the triangles are decision points set by environmental conditions. The rectangular boxes identify physical phenomena (boiling, dispersion, etc.) which are mathematically represented by calculation procedures in this handbook. While these procedures simply indicate how rapidly certain physical processes are taking place, they are essential because they help determine the extent of the hazard. Each rectangle is designated by a letter, so that a particular path may be referred to by a series of letters. This series of letters is called the "hazard-assessment code" and is identified in CG-446-2 for each chemical. Each path eventually leads to one or more circles, which are points of evaluation.

To illustrate the use of the hazard-assessment tree, consider the discharge of a material that boils at temperatures below the local water temperature, is not soluble (immiscible) in water, is lighter than water, and is not ignited either because it is non-flammable or because there is no ignition source present (path A-D-F-G). For such a chemical, we would wish to know how fast it spreads on water, boils, and disperses in air under the existing atmospheric conditions so as to determine over what distances flammable and toxic concentrations of the chemical may exist. Generalized procedures for calculating these rates are also provided in this handbook. As inputs, such procedures require information about physical properties, environmental conditions, and any special restrictions (e.g., shorelines) that might limit the chemical spreading in one or more directions. Once the path is defined, the threat can be assessed, because the critical toxicity levels and ignition limits are known and provided in CG-446-2 and hazard-assessment procedures are described here.

Other paths introduce the same, or similar, types of calculations. By indicating which calculations must be performed and providing generalized methods of making the desired calculations, this hazard-assessment manual will allow one to progress along the appropriate path and determine the potential hazard presented by a chemical discharge.

4.3.2.4 Development

Once the identity of the discharged chemical and the associated hazard-assessment code have been established, one can proceed to the final step of actually making the hazard assessment. The hazard assessment was reduced to a simple set of manipulations that required elementary calculations utilizing the graphs and tables presented in the manual. Corresponding to each letter in the hazard-assessment code is a calculation procedure displayed in graphic or tabular form. Some procedures are generalized and can apply to several chemicals, whereas others are specific for an individual chemical. Actual instructions for using the graphs and tables and making the hazard assessment were developed in a manner to facilitate quick calculations and yet be operationally simple. Furthermore, worksheets were provided for each hazard assessment code with a solved example of a hypothetical assessment on the left side of the worksheet and blanks to be filled out for the real emergency situation on the right side of the worksheet. The worksheets, graphs, and tables needed for calculations were indexed according to the hazard-assessment code they represent.

The above approach to hazard assessment was field-tested at the COTP offices in Philadelphia and Boston. The field personnel responded positively to the approach and only minor modifications were necessary prior to finalization of the assessment procedure. It was felt that the chosen approach was ideally suited to USCG field requirements and satisfied the objectives of this portion of CHRIS.

4.3.3 Considerations Involved in Content Development and Format

The primary basis for the estimation methods employed in CG-446-3 is the mathematical models that simulate the different paths of the hazard assessment tree. These models are described in Appendix C of this report.

At an early stage in the development of the Hazard Assessment Manual it became apparent that the actual assessment models themselves were quite complex and encompassed several variables that could potentially affect the prediction of total threat imposed by an accidental release of a hazardous substance. In order for a user to use the mathematical models directly would have required that he have a high level of engineering training, not only so that he might perform the necessary manipulations, but also so that he might perform the calculations accurately and fully understand the limitations and implications of the outputs of the model. Discussions with U. S. Coast Guard personnel indicated that the level of engineering skills required to directly manipulate the models may not always be available in the field and alternate approaches should be sought to model presentation.

As a result, all of the basic hazard assessment models were reduced to a generalized set of graphs, charts, tables and nomographs. The sequence of model use was reduced to a sequence of graphical and tabular analysis requiring little or no complex mathematical manipulation and only a limited understanding of the principles that led to their derivation. Each simplification of the calculational procedure was developed with the field personnel in mind and realizing that his specialized training is generally insufficient for using complicated equations rapidly to obtain the desired outputs.

Whereas the reduction of the mathematical assessment models to graphs and tables greatly simplified the complexity of the assessment procedures, it also introduced a greater degree of approximation in the output. To keep the number of graphs and tables representing each model to a workably low number, it was necessary to combine certain controlling parameters in an approximate fashion. This process, which was required for a few models, introduces a greater degree of approximation in the output. However, in all cases where such approximations were introduced the approximate solution was evaluated over the entire range of input variables and compared with the more exact solution to insure that differences in the two outcomes were minor and within the bounds of certainty requirements of the manual.

4.3.4 Validation of Numerical Values and Information Needs

Upon completion of the manual, a program of validation and numerical checks was initiated by thoroughly exercising the manual. A series of sample problems was hypothesized and solved utilizing both the manual and the original computerized version of the basic assessment models. The sample problems were chosen in such a manner that in solving them every branch of the assessment tree was utilized and each assessment model exercised. By this procedure it was possible to assure the numerical correctness of the charts, graphs, tables and nomographs presented in the manual.

In addition to verification of numerical accuracy it was also necessary to determine if the on-scene information needs and sources of these needs were realistically available under field conditions. A program of assessing the ready availability of information needs was conducted during the phase of CHRIS development related to the preparation of a sample contingency plan in Louisiana. Suggested sources for on-scene information needs were contacted and it was determined that the sources cited in the manual are reliable under field conditions.

4.3.5 Recommendations

It is recommended that the U. S. Coast Guard closely monitor the experience of field personnel with the manual. In particular it would be most useful to record:

1. The availability of information needs under real emergency situations.
2. The time span between the initial report of an accident situation and the completion of the final hazard assessment.
3. The accuracy of the hazard assessment as borne out by later occurrences.
4. Actions taken by USCG personnel based on the hazard assessment.

5. General field personnel comments on the usefulness of the manual and how it may be modified to better suit their requirements.

Such a record would allow management representatives to plan a meaningful revision of the manual and periodically update the manual and increase its usefulness.

A mechanism to continuously improve existing assessment models and introduce new models as they become available should also be developed. The introduction of any changes in the manual should be accompanied by detailed exercise sheets and an explanation of how the other CHRIS manuals may be utilized in connection with the new assessment procedures.

4.4 Response Methods Handbook, CG 446-4

4.4.1 Scope and Content

The intended content of this handbook was summarized in an appendix to the final report on the preliminary design of CHRIS, as follows:

"The Response Methods Handbook will consist of descriptive information and technical data on existing methods for responding to accidents involving the release of hazardous chemicals. It will serve as a guide to the On-Scene Coordinator and other response personnel during emergencies, aid in contingency planning and serve as a training device.

The handbook will treat both cautionary and corrective response methods. Cautionary responses include monitoring the incident, issuance of warnings, restricting access to the area, and evacuation. Corrective responses encompass commodity transfer, containment and motion control, removal, chemical and physical treatment, and dispersal and flushing. Operational, engineering, and logistic requirements associated with the different response methods will be presented and the limitations on the use of specific methods by environmental conditions will be treated. Detailed manufacturers' data on response equipment will be included in appendices to the handbook.

Methods will be presented for selecting specific response procedures based on the chemical spilled and the conditions that exist during the incident. The selection methods will be closely coordinated with information in Manual No. 2 where applicable response methods are associated with the specific chemical.

Since the principal objective of CHRIS is to furnish information required for emergency response, this handbook will utilize information contained in or derived from the other CHRIS manuals. It will be the most crucial source of information employed during emergencies (where there is sufficient time to refer to any, employ the more detailed reference guides)."

The development and refinement of the scope and content of this manual were particularly difficult because of:

- A lack of well proven and effective procedures for responding to discharges of chemicals other than oil.
- A comparative absence of response equipment and resources available to Coast Guard personnel.
- The non-existence of integrated and comprehensive texts on potentially applicable response methods.

These deficiencies in spill response state-of-the-art has required that the emergency guide contain material on possible or potential responses that have not been fully worked out nor well-proven. It also contains descriptive or textual material that might otherwise be merely referenced so that the content of the handbook could be better focused on its use during emergencies.

The manual necessarily requires that the user be well informed as to its contents prior to its use during an emergency. He also must have sufficient training and experience to assess and evaluate the limitations of response procedures presented in the manuals, the resources available to him and the conditions that prevail so as to take the most effective and proper action during an emergency.

The material that was eventually incorporated in the manual evolved through a process of successive revisions resulting from reviews and discussions between Coast Guard and ADL personnel. This manual has necessarily required more attention, input, and guidance from the Coast Guard than have other components of CHRIS.

In its final form, the manual is published in two volumes. The first contains the primary material on response methods and the second volume is an appendix which consists of a compilation of pertinent information on available equipment, suppliers and structural patching methods.

The first volume contains introductory and explanatory information, a means of selecting response methods for each of the first 400 chemicals

covered by CHRIS, cautionary response methods, corrective response methods, and a section on personal protective clothing and equipment.

Some of the special features of this handbook include:

- Brief and concise emergency guides to general and specific responses preceding each type of response.
- All major sections of the handbook are tabbed for quick reference during an emergency.
- A table that lists each of the 400 CHRIS chemicals and notes the response procedures applicable to each and the page number where the response procedure is described in the handbook.
- Tables that provide estimates of the maximum downwind travel distances and lateral dimensions of toxic and flammable vapor clouds so as to provide a quick assessment of the threat resulting from discharges of volatile hazardous chemicals.

All known viable and potentially available response methods are covered within the cautionary and corrective response categories.

The second volume contains several appendices. The largest of these is a comprehensive set of data on response equipment and materials. Each data sheet is devoted to a specific type of response equipment that is available from a specific manufacturer. Specifications and operating characteristics are given and, in many cases, a photograph of the equipment is included.

Other appendices include a listing of sources of response equipment and suppliers of acid-neutralizing agents, coagulants, flocculants, and sinking agents. A section is also provided on structural patching methods to give the user some information on this method for stopping leaks.

4.4.2 Development Procedures

4.4.2.1 Content

- Causes of Hazardous Chemical Discharges: This section was added to the handbook so as to provide an introduction to the types and

sources of chemical discharges that might be encountered by the user. The material contained in this section was developed by personnel who have spent many years conducting industrial accident and accidental discharge investigations and who have, on occasion, assumed responsibility for spill containment and cleanup. Much of the recent experience has come from numerous plant surveys and historic spill investigations conducted for the Division of Oil and Special Material Control of the Environmental Protection Agency. Spill problems associated with the transport, transfer, storage and processing of hazardous chemicals are briefly summarized in this section.

- Cautionary and Corrective Response Index: It was obvious to the developers of the handbook that there existed a need to produce an educational medium to acquaint and orient individuals (with only basic chemistry training) in the hazards and action of various chemicals upon entering a waterbody. It was assumed that USCG personnel following pollution control assignments would study this section of the manual to gain basic orientation on commonly used industrial chemicals.

The secondary objective of the index was to provide a means of instigating rapid response action and use of the handbook. In effect, the index is a summary of the Response Methods Handbook and other CHRIS handbooks.

The selection of the cautionary and corrective response actions as indicated by an appropriately positioned "X" was the joint effort of a number of highly trained and experienced chemical engineers and chemists. Each indicated action was checked and doubled checked to insure that the best possible response for any given chemical discharge was recommended.

- Sources of Information on Cautionary Response Actions: From previous studies, many of which were conducted to develop other CHRIS handbooks, and from an in-house knowledge of suitable personal and property protective procedures, the suggested actions were formulated. This knowledge was later expanded from meetings with state and municipal fire, police, and civil defense agencies, many of whom had instigated emergency/cautionary response actions under circumstances similar to, or

under actual chemical discharge conditions. The various governmental and volunteer agencies were questioned to determine the extent of service and/or equipment they could provide to the OSC in the event of a minor or massive polluting discharge.

The section on maximum distances over which hazardous gases may be harmful containing tables of distances was developed using the Hazard Assessment Handbook, CG 446-3.

- Corrective Response Actions:

  - Stop Discharge. The USN has over the years established proven damage control techniques directed toward stemming the flow of a liquid. The USN damage control procedures were coupled with generally accepted marine salvage techniques to develop this section of the handbook.

  - Containment. State-of-the-art procedures for the containment of oil slicks were adapted to the containment of lighter-than-water chemicals. To determine current state-of-the-art in containment equipment, personal contact was made with known manufacturers and "information requested" ads were placed in various marine pollution-oriented newsletters and technical journals; excellent response was received. Selected personnel attended pollution control seminars to meet with manufacturers' representatives and to gain technical and cost data on various types of containment equipment. The work procedures described, coupled with a literature search and discussions with equipment users, provided the data content for this section.

  - Collection and Recovery. Initial action duplicated that just described. The knowledge was extended by discussions with manufacturers and federal and industrial users of such equipment. In most instances, collection and recovery equipment (skimmers, herders, and the like) had been subjected to a physical survey/inspection prior to inclusion in the handbook.

- Chemical and Physical Treatment: This information was taken from the literature on treatment methods and a significant amount of the background material derived from the supplementary study on amelioration requirements (see Section 6.2 of this report).

● Clean Shoreline and Salvage of Waterfowl: These two sections were added at the request of the Coast Guard Project Monitor and the informational content primarily came from the references cited in the handbook.

● Protective Clothing and Equipment: This section was also not included in the original specifications for this handbook. Personal protection is so important to adequate and safe response to chemical discharges that it was deemed important that information be provided on equipment that is available and its compatability with specific chemicals. The information for this section primarily came from the reference cited in the handbook.

4.4.2.2 Data Review

The reviewers of the handbook included experienced chemical engineers, naval architects and marine engineers, chemists, oceanographers, ocean engineers, mechanical engineers and others well versed in chemical discharge response actions. Technical editors and illustrators further contributed to the handbook content.

The equipment manufactuers also checked the response equipment data sheets prior to inclusion in the handbook Appendix. It is stressed that the data provided were manufacturers' data; no tests were conducted to substantiate or refute the information contained in the equipment data sheets.

4.4.2.3 Revised Specifications

The state-of-the-art of response technology is being upgraded by federally-sponsored research and development programs, by the chemical and transport industries and by equipment manufacturers. This effort is expected to proceed at such a rate that the next revision of the handbook may require substantial changes in both format and content. Because of the large changes that may be required as the result of progress in the methodology of responding to chemical discharges, and because of changes that may derive from a study of the utilization of CHRIS, it has been concluded that a revision in the preliminary specifications for this handbook is not warranted at this time.

4.4.3 Considerations Involved in Development of CG 446-4

Some of the more important topics that required discussion and reviews, and, in many cases, revisions to a series of drafts of this handbook include the following:

- The initial draft of the handbook was written in a textbook fashion in an attempt to cover all of the basic information on existing response technology. Although such a source of information is sorely needed, this style and comprehensiveness was not suitable to an emergency guide. Accordingly, much of the original material was eliminated or condensed and the format was rearranged.

- The first draft of the handbook also tended to duplicate some of the information given in other CHRIS handbooks. Decisions as to how much of the information that could be found in other parts of CHRIS should also be added to this handbook were difficult to make. The addition of too much information resulted in excessive duplication whereas too little information could cause loss of time during an emergency as the result of the need to refer to other handbooks. The present draft of the handbook represents a compromise in the informational content from this standpoint.

- The cautionary response procedures were derived from perceived scenarios and from limited experience with actual chemical discharges. As a result of the lack of well defined response methods having been developed to date, the procedures, as described in the handbook, are quite general in nature and leave much of the detail and decisions on how to conduct these responses up to the intuition and experience of the users and experts that may be able to provide additional guidance.

- The presentation of tables that give maximum distances over which hazardous gases may be harmful introduces a particularly acute problem. The objective of these tables was to provide a quick approximation of the extent of the threat presented by a potential

discharge of the chemicals that were listed. A quick assessment of the threat could enhance the speed with which responses to the discharge might be implemented.

Since a quick approximation of the threat obviated the citing of distances for a variety of meteorological and other conditions that might prevail, the distances were estimated on the basis of the worst conditions that might exist at the time of the accident (and this is explained in some detail in the handbook itself). In taking the worst conditions and in being conservative in the estimates very large distances over which hazardous gases may be harmful are cited.

These distances may alarm those that consider the safety in the transport of some of these chemicals to be adequate. Also, if the conservativeness in the estimates of the hazards is not properly considered during an emergency, the resulting responses could conceivably be excessive. Nevertheless, it was concluded that the tables, as presented in the handbook, serve the basic purpose that was intended and the user should be able to determine whether and when to use the Hazard Assessment Handbook to obtain more realistic values.

- Some of the corrective responses and particularly the chemical and physical treatments include responses that have not been well proven and in some instances may be prohibited under special conditions. It was concluded, however, that it was better to provide some possible techniques that might be considered during an actual accident than to leave the user without any information at all as to possible courses of action.

4.4.4 Conclusions and Recommendations

The following overall conclusions and recommendations apply to the Response Methods Handbook, CG-446-4.

(1) The ability of the Response Methods Handbook to satisfy the needs of the user during a hazardous chemical spill emergency suffers

badly from the lack of a well developed response technology. There is a dire need for the development of information, procedures, and equipment for response to hazardous chemical discharges. This applies to cautionary as well as corrective responses.

(2) A textbook containing existing information, procedures, and equipment descriptions for responses to hazardous chemical discharges needs to be developed and published. A basic test of this kind would help to improve upon the utility of the Response Methods Handbook by providing a means of upgrading the training of the potential user.

(3) The Response Methods Handbook should be revised after it has been implemented for about one year and after its utilization has been evaluated. Provision should be made for subsequent periodic revisions as response technology is improved over the next several years.

4.5 Hazard Assessment Computer System (HACS)

4.5.1 Scope and Content

4.5.1.1 General Description of HACS

The HACS is a fully developed computer system designed to provide a resource at Coast Guard Headquarters for making quick assessments of potential threats to life and property caused by accidental chemical discharges. In effect, it is a computerized revision of the Hazard Assessment Handbook, but since it is not confined by the limitations imposed on the manual where simplifications had to be made to facilitate field use, it provides a wider variety of analyses to be performed and can achieve a higher level of accuracy in the predictions derived from it. A relatively detailed description of HACS and instructions on its use have been provided in a Users Manual(6) designed for Coast Guard personnel who will operate the system.

4.5.1.2 Origin of HACS

Methods for estimating the threat produced by the accidental release of a hazardous material on a waterway were discussed in Arthur D. Little, Inc.'s final report to the U.S. Coast Guard on "The Preliminary System Development of the Chemical Hazards Response Information System (CHRIS)," May 1972. It was recommended therein that basic mathematical hazard assessment models be developed and documented in a handbook as one essential component of CHRIS. This handbook would be used principally by Coast Guard field personnel during emergency spill situations.

In a companion recommendation, the development of a computerized counterpart of the Hazard Assessment Handbook was advocated. The Hazard Assessment Computer System (HACS), to be operated only by Headquarters specialists on behalf of field personnel, was envisioned to significantly support and augment the handbook version. The need for HACS derived in part from extensive discussions with the National Academy of Sciences

Coast Guard Advisory Committee.

4.5.1.3 System Objectives

The main objective of HACS is to provide an accurate, yet rapid, estimate of hazards presented by a spill (or potential spill) and display the estimates in the form of computer plots and tables depicting the effects of existing or likely environmental conditions on the extent of hazard. HACS should achieve the following:

- Enable CHRIS Headquarters specialists, on request from field personnel, to exercise a series of complicated mathematical expressions with accuracy and rapidity during an emergency spill situation.
- Obtain graphic display of hazard conditions and transmit them via facsimile to field personnel.
- Provide CHRIS Headquarters with an operating model sufficiently flexible to incorporate new advances in hazard assessment.
- Provide an excellent tool for training and educating field and new Headquarters personnel in the formulation and use of hazard assessments.

4.5.1.4 System Attributes

The Hazard Assessment Computer System provides a rapid and accurate method of evaluating the hazard resulting from complicated physical phenomena that can occur when a hazardous chemical is released on water. We have stated our belief that HACS, as operated by Headquarters specialists, can significantly support and augment the field manual. It is capable of accomplishing the following:

Emergency Response

- Provide the means to check independently and confirm hazard assessments carried out in the field.
- Facilitate the assessment of different sets of environmental conditions that are postulated for the further evolution of the emergency situation.

- Provide a method for simulating the time history of the development and attenuation of the spill hazards.
- Furnish the means for assessing the effect of conservative handbook assumptions on the estimate of the hazards that prevail.
- Provide graphical output (e.g., concentration versus location) giving more useful emergency information.
- Allow inverse solutions—that is, estimates of the time and/or location that a given level of hazards may occur versus the level of hazard predicted for a given time and/or location.

Non-Emergency Response

- Provide a training tool for Headquarters personnel concerned with both hazard assessment and response.
- Furnish a basis for contingency planning and risk analysis studies.

Concerns

During the development of HACS a number of important concerns affecting its utility and frequency of use were raised. These are as follows:

- Communication channels should be available so that personnel can readily gain access to Headquarters specialists who operate HACS.
- A staff of Headquarters specialists expert in the use and interpretation of HACS is required.
- Access to the CDC 3300 computer must be significantly upgraded to provide near "real-time" response.

4.5.2 Considerations Involved in the Development of HACS

The internal structure of the HACS and much of the philosophy underlying the initial design and subsequent implementation of the system are derived almost exclusively from the concept of a hazard assessment "tree" in which a series of generalized models of chemical

rate processes are linked to form a "path" leading to an assessment of the hazard associated with spills of specific chemicals. Each rate model describes a chemical process in general terms, while the formation of a hazard assessment path (linking the models) is determined by chemical-specific properties.

Once a path is established, the computations along a hazard assessment path lead to outputs describing the potential hazard, and these may be carried out repetitiously to evaluate the variation in potential hazards associated with changes or uncertainties in conditions at the spill. Because of the range of conditions possible at the scene of a spill, and the variation possible in chemical specific behavior, different combinations of hazards (e.g., thermal radiation, toxic vapor dispersion) may occur under different conditions. The methodology followed was to allow assessments of all potential hazards, covered by the hazard assessment "tree."

The mathematical models of chemical rate processes, embodied as a series of subroutines, are complex and require input data describing the physical properties of a chemical and the environmental conditions at the scene of a spill. Other input data are also required to control the modeling process and, where available, for selection of optional output displays. As different models are linked to form an assessment path, additional input data to a model may be obtained from the execution of a rate process model preceding it on the path. Three fundamental concerns which were inherent in the design and implementation of the HACS were:

- In any real spill situation, sufficient data to satisfy all the input requirements of each rate model for any specific hazard cannot always be expected to be known either at the time of the spill, or during the period in which assessments of the hazard associated with the spill are critical.
- The hazards estimated by the rate models are dependent on assumptions embodied in the modeling process and the quality of the available data. During the course of a

spill, observable phenomena, if available, should be used to improve the overall quality of the estimated hazards.

- The capabilities of the rate models provide for a range of different hazards, not all of which will occur during any particular spill. Thus, along any path, input data are required only for the models on the path and not for the full set of rate models.

From these considerations arose the concept of a data bank in which available information is stored, then made available as necessary for the execution of the chemical rate process models. Based on the philosophy of permitting on-scene observed behavior to supercede computed estimates, individual data items were assigned attributes of "goodness" depending on their source. The data priority scheme which evolved permits any data item to be replaced at any time should a "better" value for that item become available. Finally, in view of (a) the extensive data requirements and the potential of user omission, and (b) the possibility of observed characteristics which would enable the successful execution of a rate model without requiring the complete execution of prior models in the path, the premise was developed that HACS should operate under all possible conditions of available information and, as a last resort, automatically select values for any unspecified data items from a "default" file.

The design of the HACS data files and rate model structure assumed a tutorial mode of useage, in which the system would operate with whatever information was available or provided, and generate output reports (audit) describing all computations and alternatives selected (e.g., default value used). By reviewing each output run, users are directed to any requirements for additional data which may exist and may replace any item with improved values, if available.

The final major consideration in establishing the structure of the HACS was the requirement to provide chemical specific properties, resulting in the compilation and implementation of a separate data base together with the necessary interface to HACS. In the structure of this data base, provision was made for a master set of physical property

data, not all of which are applicable or were available for each chemical or compound. These conditions were also accommodated by the development of a priority scheme, a scheme in which individual data items were assigned attributes describing their status (missing estimate, exact), which was integrated with the overall data priority scheme applied in HACS.

The conceptual details of the implementation design then followed in a straightforward manner, dealing with the tasks on input data processing, output generation (printed and plotted), data base maintenance (update and report), and file creation. Since HACS was to be operated on the computer system at USCG Headquarters, program coding was carried out consistent with the conventions, capabilities, and limitations of the installation.

In the early stages of the work, it was agreed that, in the interest of economy and to minimize potential conversion difficulties, most of the computer system programming and implementation tasks would be carried out using the computer system at USCG Headquarters. During the course of the project, the limited availability of the USCG computer system contributed to several delays and schedule changes, but conversely, several installation characteristics and limitations were encountered which would have required a more extensive conversion effort than would have otherwise been anticipated had HACS been fully developed on a different system.

The program code developed for HACS became extensive, and together with requirements for data storage, eventually exceeded the memory space available on the USCG computer system. Considerable technical difficulties were encountered during initial attempts to segment the system into overlays and, as a result, during most of the implementation phase, HACS was operated as two separate programs (hazard assessment and plot output) which required additional development for processing the transfer of data between these programs. This problem reoccurred continuously as adjustments had to be made as the size of the program grew. Through

the assistance of the Coast Guard AMVER group in New York and the Control Data Corporation, an operational overlay structure was eventually developed, but the basis for the original difficulties was never fully diagnosed.

During the development and initial use of HACS, the preparation of graphic output required the use of the remote plotter located some distance from the Coast Guard computer facility, and it was necessary to utilize USCG plotting programs which might otherwise have not been available. The preparation of these outputs required an assessment run to produce a magnetic tape for off-line plotting, travel to the remote plotter, preparation of the final plotted outputs and return travel. This mode of operation caused further delays in project schedules, although considerable assistance and cooperation were provided by Coast Guard personnel and demonstrated that this plotting system would not be feasible for emergency situations. As a result, the ability of HACS to generate graphical output displays was improved by the inclusion of line printer plots obtained simultaneously with assessment runs. While the off-line plotting capability may still find applications in the preparation of final displays for reports and similar purposes, the remote location of the plotter severely restricts this type of display in connection with actual spill situations.

4.5.3 Conclusions and Recommendations

(1) HACS, as it has been developed on the USCG Headquarters computer system, embodies the original concepts of design and provides for detailed assessments of complex spill situations. The system design and implementation are based on the modular approach embodied in the hazard assessment "tree" and HACS is adaptable to change and further evolution as further refined assessment methodologies or additional user requirements arise.

(2) HACS was initially intended for use by hazard assessment specialists at Coast Guard Headquarters who possess a fundamental appreciation for the nature of the physical and chemical processes modeled therein. For this reason, it is assumed that

users have familiarized themselves with CG-446-3, as well as with the report documenting the development of the mathematical models utilized by HACS (see page C-1).

(3) HACS can be an extremely powerful tool in the hands of an experienced hazard assessment specialist, who can properly formulate a problem for presentation to HACS, and then correctly interpret the significance of the results obtained. At the same time, however, the system could inadvertently be misused by applying it to situations which were either (1) specifically excluded from consideration by the designers, or (2) unanticipated by them. The system designers know of no automatic way to prevent misuse, except to caution users to be "reasonably" familiar with the methodology underlying the assessment models. Several sections have been included in the HACS User Manual discussing limitations and accuracy related to physical process modeling, and providing further detailed observations pertaining to each assessment model. As the application of HACS progresses to more varied spill conditions, other as yet not anticipated or discussed effects of modeling limitations and/or approximations may be encountered.

(4) In view of the above, HACS at present is not directly available to Coast Guard field personnel except through Headquarters specialists who will operate HACS on their behalf. As experience is gained in using HACS, this policy may be reappraised to permit direct field access, subject to the availability of necessary terminal equipment and computer inquiry processing capability. At the present time, the system operates only in a batch mode and is not available on a "real-time" basis for emergency hazard assessment.

(5) The present availability of computer time on the CDC 3300 computer system at USCG Headquarters indicates a potentially severe problem in the future use of HACS which has been discussed on other

occasions. During development, installation and initial use, turn-around time for standard batch runs has varied from several hours to overnight or longer, and then raises a very serious question as to the degree of usefulness of HACS, when fully installed in actual spill situations.

(6) The turn-around time being experienced involves primarily operational policies and priorities, not technical considerations related to the development of HACS or the capabilities of the CDC 3300. Also, extended implementation tasks are in the process of completion and operational experience with the system by Coast Guard personnel has been necessarily limited. For these reasons, specific recommendations as to improving real time capability cannot be made at this time.

(7) It is recommended that the Coast Guard review the availability of its CDC 3300 resources with respect to HACS and determine whether or not a substantial improvement will be achieved when HACS has been fully integrated in the operating environment. The degree to which improved availability will be necessary is such that the elapsed time between submission of input for an assessment run, and completion of the line printer reports probably should be much less than 15 minutes, no matter what time of day the run is submitted. If this degree of response time cannot be achieved, HACS will be of insignificant usefulness in any real spill situations and consideration should then be given to installing the system on an alternate computer facility. HACS could then continue to operate on the CDC 3300 at Coast Guard Headquarters for research and investigative purposes, but high priority assessment runs would be performed at the alternate facility.

4.6 Regional Contingency Plan Data Base

4.6.1 Background

The Regional Contingency Plan Data Base was originally conceived as one of the basic reference guides (initially referred to as Manual No. 3) of CHRIS. After some reflection, however, it became apparent that, although these data bases are essential to CHRIS, they should remain as a component of the Regional Contingency Plans but, at the same time, should conform to CHRIS needs. Furthermore, it was decided that the individual data bases could be most effectively formulated by Coast Guard regional personnel who had knowledge and contacts with local sources of information.

Although the data bases were to be developed separately and independently from CHRIS, it was mandatory that their content and presentation meet the needs of CHRIS. To insure that the data bases conformed to CHRIS needs, ADL was assigned the task of developing a sample data base and from the knowledge gained in this effort, formulated a development plan that could be used by Coast Guard personnel in putting together data bases for all of the Coast Guard regions.

Accordingly, a Regional Contingency Plan Data Base for Louisiana was drawn up by ADL. Office space was assigned to ADL personnel at the New Orleans COTP, and a data base development team worked in these offices over a period of approximately six months. The procedures used and problems incurred are reflected in the Development Plan that evolved from this experience.

At the outset, it was planned that the development of the Regional Contingency Plan Data Base for Louisiana would involve the acquisition of all of the types of information required and all of the procedures necessary to obtain it. Completeness of the data was not an objective, however, since this development was to be for illustrative purposes rather than an attempt to provide a thoroughly detailed and complete document for New Orleans COTP personnel.

The product of the New Orleans effort was a comprehensive illustrative example of a National Contingency Plan Data Base. This has been published and copies furnished to the Coast Guard.

During and following the development of the Louisiana data base, the Development Plan for Regional Contingency Plan Data Bases was formulated. This plan, containing guidance on the development of the data bases and special considerations involved in putting them together, is described in the following section.

4.6.2 The Data Base Development Plan

4.6.2.1 State Tabs

The purpose of the Regional Contingency Plan (RCP) Data Base is to provide a data bank of emergency response information for inclusion in the Regional Contingency Plans. These data will be published as an Appendix to the RCP. The resulting data base will be used by the On-Scene Coordinator (OSC) in the event of an accidental chemical discharge.

The purpose of the Development Plan is to provide guidance to U.S. Coast Guard District personnel in the collection of emergency response data for inclusion in the RCP's.

Since the RCP tabs are to be used by an OSC who may not be familiar with the region where the emergency has taken place, they have been organized to quickly provide information on local conditions and sources of aid. As all tabs will follow a standard format regardless of region, an OSC working under emergency pressures will be able to find the information needed as quickly as possible. Each state's tab will provide data related to the facilities and life which might be endangered by the chemical hazard as well as a full description of what is available in the way of local assistance, both in terms of expert manpower and equipment. The tab will provide data in a quickly accessible and easy-to-use form. For example, vulnerable facilities will be listed not only by name, but also will include day

and night telephone numbers of responsible individuals.

To determine the easiest way to compile the data base, a pilot study team went through the same process described in the development plan at the COTP, New Orleans (with help from COTP Sabine). The pilot study team placed principal emphasis on the development plan itself and did not attempt to compile a fully comprehensive data base in the time available. The pilot tab represents, however, an example of the types of information to be collected.

4.6.2.2 Contents of a State Tab for a Regional Contingency Plan Data Base

The Regional Contingency Plan state tab contains:

- Information which is necessary to the OSC at the site of a discharge incident and which has been compiled into an Appendix covering a specific state and included as a tab in the respective Regional Contingency Plan. The Appendix consists of a geographic directory, an assistance directory and references.
- Detailed information which has been collected in the process of compiling the Appendix (usually in the form of filled-out questionnaires), and which is filed at the office of the respective COTP.

The content of the state tab for a Regional Contingency Plan Data Base is outlined in Table 3.

TABLE 3

CONTENTS OF A STATE TAB FOR A REGIONAL CONTINGENCY PLAN DATA BASE

I. GEOGRAPHIC DIRECTORY

A. Index Map

This map covers the entire area under Coast Guard jurisdiction in any given state and identifies the sectional maps on which detail data will be found.

B. Sectional Maps

Sectional maps identify the location of cities and towns, industrial and commercial facilities, national parks, wildlife preserves, beaches, and other vulnerable resources, as appropriate. The populations of cities and towns are listed on a separate page. Each map is backed up by data sheets which summarize pertinent descriptive and emergency information for each facility identified on the map. Specific items included on the data sheets are:

1. Facility name.
2. Facility type (chemical manufacturer, etc.).
3. Location on body of water (river mile, if applicable).
4. Address.
5. Surroundings.
6. Access roads.
7. General information summary.
    a. Employees (day, night, weekend).
    b. Production volumes.
    c. Mutual aid groups.
    d. Laboratory facilities (other than routine quality control).
    e. Response teams.
    f. Expertise available to OSC.
    g. Water quality measurements performed.
8. Piers, wharves, docks.
    a. Principal use, size.
    b. Frequency of use.
    c. Construction.
    d. Lighting.
    e. Electricity (vessels).
    f. Water supply (vessels).

Table 3

(Continued)

9. Water intakes.
   a. Location.
   b. Amount (cfm or gal/hr).
   c. Use of water.
   d. Depth of intake.
   e. Vulnerability to discharges.
10. Chemical storage (other than small amounts or laboratory sample lots).
11. Pipelines (size, substance transmitted, location of shut-off valves).
12. Persons responsible and alternates.
   a. General facility.
   b. Pipelines.
   c. Experts and manpower.
   d. Water intakes.
   e. Laboratory assistance.
   f. Response team.
13. Physical resource summary.
   a. Firefighting materials and equipment.
   b. Personnel protective devices.
   c. Detection and monitoring equipment.
   d. Pollution cleanup equipment.
   e. Transportation and communications.

C. Waterworks Warning Network

In those states where a waterworks warning network has been organized, the specific emergency information taken from the network will be shown.

D. Shoreline Characteristics and Ownership

1. Maps (use special U.S. Army Corps of Engineers maps where available).
2. Descriptive information.

Table 3

(Continued)

II. ASSISTANCE DIRECTORY

A. Contractors and Suppliers

1. Cleanup contractors

   For each contractor:

   - Name.
   - Address.
   - Person to be contacted—name and title, day and night, telephones.
   - Types of capabilities.
   - Restrictions and limitations.
   - Previous experience.

   a. All services contractors.

   b. Equipment dealers.

   c. Chemical dealers.

   d. Hay dealers.

   e. Chemical/oil disposal services.

   f. Steam cleaning services.

2. Laboratories

   For each laboratory:

   - Name.
   - Address.
   - Relevant capabilities.
   - Person to be contacted—name and title, day and night, telephones.

B. Mutual Aid Groups

For each group:

- Name.
- Address.
- Applicable service.
- Person to be contacted—name and title, day and night, telephones.

1. National or regional industrial associations.

2. National or regional company groups.

Table 3

(Continued)

3. Local resource pools.

   a. Municipal forces and combinations.
   b. Industrial forces.

4. Federal resource pools.

5. Volunteer ecology groups.

6. Social service organizations.

C. Experts

For each area of expertise:

- Name and title of contact.
- Address.
- Day and night telephones.
- Limits of expertise.

1. Fish and wildlife.

2. Water quality.

3. Discharge analysis.

4. Engineering.

D. Government Agencies

For each agency:

- Nature of available cooperation.
- Capabilities and jurisdiction.
- Address.
- Person to be contacted—title (name, if known), telephone number (night telephone, if available).

1. Federal Government.

2. State and local government.

   a. State police.
   b. County sheriffs.
   c. Police departments.
   d. Fire departments.

Table 3

(Concluded)

E. Water Quality Agencies

For each agency:

- Name of agency.
- Address.
- Type of assistance available.
- Person to be contacted—title, telephone number.

F. Meteorological Agencies

For each agency:

- Name of agency.
- Address.
- Type of assistance available.
- Person to be contacted—title, telephone number.

G. Physical Resources Matrix

List on special form the facilities and major categories of physical resources available at each facility.

III. REFERENCES

List all categories of pertinent data, such as water quality baselines, weather guides, oil field listings, maps showing pipeline crossings, and others which because of their bulk have not been included in the Appendix, but which are located at the COTP office.

4.6.2.3 Contents of Development Plan

The development plan includes two general areas:

- A description of the data gathering process, lessons learned from the conduct of the pilot study, and specific procedures recommended to facilitate the data collection process.
- Specific data collection guides, such as questionnaires, interview guides and sample data sheets covering various types of data in the geographic directory and assistance directory.

The content of the Development Plan is outlined in Table 4.

TABLE 4

CONTENT OF THE DEVELOPMENT PLAN FOR
REGIONAL CONTINGENCY PLAN DATA BASES

I. INTRODUCTION

   A. PURPOSE OF THE DEVELOPMENT PLAN

   B. RCP DATA BASE DEVELOPMENT

   C. PILOT STUDY

   D. PURPOSE OF THE STATE TABS USED IN THE REGIONAL CONTINGENCY PLAN APPENDICES.

   E. THE STRUCTURE OF THE STATE TABS

II. THE DATA COLLECTION PROCESS

   A. DATA GATHERING

   B. PLANNING

   C. STAFFING AND SCHEDULING

   D. COMPILING LISTS

   E. LEVEL OF DETAIL

   F. MONITORING

III. GEOGRAPHIC DIRECTORY

IV. DATA COLLECTION GUIDES FOR THE GEOGRAPHIC DIRECTORY

   A. COMPILING LISTS OF FACILITIES

   B. COLLECTING INFORMATION ON WATER INTAKES

   C. COLLECTING DATA ON NATURAL FEATURES

   D. INFORMATION ON WILDLIFE

   E. COLLECTING DATA ON SHORELINE CHARACTERISTICS

Table 4

(Continued)

V. ASSISTANCE DIRECTORY

A. PHYSICAL RESOURCES MATRIX

VI. DATA COLLECTION GUIDES FOR THE ASSISTANCE DIRECTORY

A. INTERVIEW GUIDES FOR CONTRACTORS & SUPPLIERS—CLEANUP

B. CONVERSATION GUIDE FOR CONTRACTORS & SUPPLIERS—CLEANUP

C. INTERVIEW GUIDE FOR CONTRACTORS & SUPPLIERS—LABORATORIES

D. CONVERSATION GUIDE FOR CONTRACTORS & SUPPLIERS—LABORATORIES

E. SAMPLE DATA SHEET—CONTRACTORS & SUPPLIERS

F. INTERVIEW GUIDE FOR MUTUAL AID GROUPS

G. CONVERSATION GUIDE FOR MUTUAL AID GROUPS

H. SAMPLE DATA SHEET—MUTUAL AID GROUPS

I. INTERVIEW GUIDE FOR EXPERTS

J. CONVERSATION GUIDE FOR EXPERTS

K. SAMPLE DATA SHEET—EXPERTS

L. INTERVIEW GUIDE FOR FEDERAL GOVERNMENT AGENCIES

M. CONVERSATION GUIDE FOR FEDERAL GOVERNMENT AGENCIES

N. INTERVIEW GUIDE FOR STATE & LOCAL GOVERNMENT AGENCIES

O. CONVERSATION SHEET FOR STATE & LOCAL GOVERNMENT AGENCIES.

P. SAMPLE DATA SHEET—FEDFRAL, STATE & LOCAL GOVERNMENT AGENCIES

Q. CONVERSATION GUIDE FOR HEALTH DEPARTMENTS

Table 4

(Concluded)

R. COLLECTING DATA ON WATER QUALITY & WATERWAY CHARACTERISTICS

S. COLLECTING METEOROLOGICAL DATA

VII. APPENDIX

SAMPLE FACT SHEET/QUESTIONNAIRE

A. GENERAL INFORMATION

B. CHEMICAL AND PETROLEUM STORAGE

C. WATER INTAKES

D. PIPELINES

E. LABORATORIES, EMERGENCY RESPONSE GROUPS, AND HUMAN RESOURCES

F. DOCKS AND ANCHORAGES

G. PHYSICAL RESOURCES

NOTES TO FACT SHEET/QUESTIONNAIRE

A GUIDE FOR USING THE QUESTIONNAIRE

4.6.3 Conclusions and Recommendations

Conclusions and recommendations made upon the completion of the Regional Contingency Plan Data Base Development Plan consist of the following.

(1) The illustrative example of a State Tab for a Regional Contingency Plan Data Base along with the Development Plan itself, provides the guidance and insight necessary for Coast Guard personnel to develop state tabs for all Coast Guard regions.

(2) Since not all of the state tabs may be compiled at the same time, it is recommended that provisions be made for Coast Guard personnel who develop the first of the state tabs to pass along pertinent information on their experience to those who have yet to compile their

(3) As with other components of CHRIS, effort should be expended during the utilization study to assess and evaluate the content and presentation of the state tabs that have been developed at the time of the study.

(4) To reduce the number of separate requests from regions to such agencies as EPA, U.S. Army Corps of Engineers, U.S. Geological Survey, and others, the collection of such data should be centralized through the U.S. Coast Guard Headquarters.

(5) Since local Corps of Engineers personnel usually do not know about all the information that is available from the Corps, this information should be identified, collected, and distributed through a central effort from the U.S. Coast Guard Headquarters.

(6) Since a number of COE Divisions issue reports which cut across the lines of Coast Guard districts, such reports should be obtained through the Coast Guard Headquarters and forwarded to the respective districts.

(7) To assist the districts in establishing relationships with other government agencies on a local level, definite policies for such cooperation should be established through the U.S. Coast Guard Headquarters and the headquarters of the respective agencies.

(8) To increase the response to requests for information from industry, the Coast Guard should prepare a policy statement saying that no data will be solicited or incorporated in the data base, if in the opinion of the respective company the publication of such data could result in misues of the information that might result in personal injury or damage to property.

5.0 CHRIS TRAINING

5.1 Scope and Content

Arthur D. Little, Inc., designed, developed, and conducted instruction programs for Coast Guard personnel in the use of CHRIS. Specifically, this effort consisted of:

- The design of an intensive course to be given as part of the Marine Protection School at the Coast Guard Reserve Training Center at Yorktown, Virginia and the conduct of this course for instructors at Yorktown. The training course included a teacher training program, teacher's guide, and follow-up counseling on how to use the instructional materials.
- The development of an intensive course and instructor's guide for the use of personnel in the National Strike Force. The purpose was to teach Strike Team members how to use CHRIS, how to introduce the system and how to provide additional training in the use of CHRIS. The Strike Team training program was conducted at the Gulf Strike Team offices in Mississippi.
- The development of a formal presentation to non-users describing the CHRIS system. Assistance was provided in the use of the presentation when it was first given by Coast Guard personnel.
- The development of additional problems and cases for use by the Strike Teams in teaching CHRIS and a CHRIS problem book which would allow personnel already familiar with CHRIS to review and practice with the system.

The Yorktown course and the Strike Team courses consisted of briefings, slide presentations, notes and mostly problems and cases. These problems and cases were designed to simulate a chemical discharge incident. When possible they were modeled after actual reported incidents. Their purpose was to focus on using CHRIS to analyze and assess particular situations, alternatives, and risks and think through sound courses of action. It was planned that personnel would learn to use CHRIS as a tool in problem-solving and would combine the information and analytical routines found in CHRIS

with actual situational factors. For this reason the cases tended to contain fuzzy and incomplete facts which the learner would have to evaluate before he could apply CHRIS - much as he would be required to do in an actual spill situation.

The briefings, notes, and problems were arranged in the order that CHRIS would be used: First Response, Second Response, Precautionary Response and Corrective Response; and, therefore, certain of the cases were used over again after the discussion of each new CHRIS handbook. The solutions were better as more of CHRIS became available to the student and the solutions were different as later responses were called for.

The briefings were written for instructors and contain references to slides already distributed to Yorktown instructors and Strike Team personnel. These were based on the CHRIS manuals and on other elements of CHRIS such as HACS. Figure 4 is an example of a page of briefing on A Condensed Guide to Chemical Data, CG-446-1.

Notes were written for the learner in which CHRIS was further elaborated upon and where basic skills needed for the system were discussed in the form of nomographs. Figure 5 is an example of a page from a note on basic chemistry - a basic skill necessary for the use of CHRIS.

Figure 6 is an example of a problem case used in the Yorktown training course. Most of these cases had accompanying nautical charts to help orient the learner and make his decision more precise.

5.2 Development Procedures and Considerations

With the exception of the non-user presentation, the CHRIS training program was designed with one primary objective; that is; to educate people to use the system. This required that training should provide as much practice and exercise of judgment as could be built into the program. The following steps were carried out in formulating the training program:

- Assessment of Need - The activities and decisions that personnel will need to carry out in using the system were established by thoroughly reviewing the information and conclusions that were derived in the preliminary system design of CHRIS This task was accomplished by an educational advisor and members of the ADL team

Figure 4

Instructor's Note on the Condensed Guide to Chemical Hazards

(Slide: title)

The actions undertaken in response to the discharge of a hazardous material can be separated into two categories, an immediate or primary response mode and an extended response mode. This is shown schematically in Figures 1 and 2.

2) Slide: Primary Response

Primary response generally includes the actions of those people who discover and report the discharge and of the response personnel who first arrive on-scene. These people are generally not hazardous materials specialists and do not have any special response equipment. Primary response actions are basically "first-aid" actions intended to minimize or forestall detrimental effects.

3) Slide: Secondary Response

The extended response mode includes evaluation of the situation by the responsible officials (i.e. the OSC) and implementation of efforts at containment and clean-up.

The Condensed Guide to Chemical Hazards, CG-446-1, is intended to be a compact convenient source of chemical-related information pertaining to hazardous materials that may spill into water. It is intended for the use of personnel who may arrive on-scene first and need readily available, easily understood qualitative information on the nature of the chemical and the situation confronted.

4) Slide: Objectives

The goal of CG-446-1 is to assist these personnel in quickly determining what actions should and should not be taken immediately to safeguard life and property and to minimize damage to the environment.

The manual is intended for Coast Guard components that generally will have little or no facility for actively responding to the incident. That is, they are not expected to have significant fire fighting capability nor equipment to contain and remove spilled material. Neither do they, at least now, usually have protective equipment such as special clothing and breathing apparatus.

Figure 5

NOTE ON THE CHEMISTRY OF HAZARDOUS MATERIALS

While it is not necessary to know a large amount of chemistry to use CHRIS, a basic *understanding of what happens when chemicals interact with water and air* can be useful in evaluating chemical discharge incidents.

Everyone is familiar with the differences between solids, liquids and gases. A chemical can exist in any of these three forms under the proper conditions. We all know that water, for example, is a solid (ice) below 32°F, a liquid between 32°F and 212°F and a gas (steam) above 212°F. Any gas can be made into a liquid if the temperature is made low enough and the pressure high enough. Natural gas becomes liquefied natural gas (LNG) when cooled to -260°F.

Gases are usually shipped either liquefied or compressed.

When a compressed gas is discharged, the gas rapidly escapes from its container since the pressure inside the container (several thousand pounds per square inch) greatly exceeds the outside pressure (atmospheric pressure is approximately 14.7 pounds per square inch). The gas forms a cloud or plume which disperses. It is important to know where the gas cloud is going and the rate at which its concentration falls off in order to assess evacuation strategies when highly toxic (e.g., chlorine) or flammable (e.g., gasoline) vapors threaten to engulf large areas.

The single largest factor governing gas (or vapor) dispersion is local weather. Dispersion caused by local wind conditions and air temperature differences have considerable influence on dilution of the gas cloud.

When a liquefied gas is discharged on water, it will either float, sink, or dissolve depending on the liquid's density and solubility. A liquefied gas like LNG *(insoluble, lighter than water)* will spread across the water surface in a manner similar to oil. However, while this liquefied gas spreads it is also boiling since the air and water are both above the liquefied gas' boiling point, and the vapor that boils off disperses.

Some liquefied gases (e.g., chlorine) sink in water. These chemicals will boil below the water surface. Other liquefied gases (e.g., anhydrous ammonia) are partially soluble in water and will produce little or no vapor.

When a gas is heated the pressure it exerts increases. The pressure in gas cylinders heated by a nearby fire will increase and cylinders can explode should the pressure rise enough.

Materials shipped as liquids will sink, float or dissolve when discharged on water. All liquids have vapor pressure — that is, the liquid tends to evaporate. Liquids with high vapor pressures evaporate quickly; those with low vapor pressures evaporate slowly. A high vapor pressure liquid (e.g., gasoline) presents a vapor dispersion hazard.

<u>Figure 6</u>

KEY BISCAYNE

At 1240 on 26 August 1972, the operations office at COTP NOLA was notified by the Coast Guard Rescue Coordination Center (RCC) in NOLA that a Liberian Flag cargo vessel, the <u>M/V Key Biscayne</u> was aground at mile 59 AHP in the Mississippi River and that there was a fire aboard in the number three hold.

COTP immediately began attempts to contact the <u>Key Biscayne</u> via radio-telephone, and at approximately 1250 contact was established. The pilot, Donald Johns, reported that the fire had been discovered at approximately 1015 and was being fought by the crew utilizing the shipboard firehoses. The master, afraid of sinking due to firefighting water in hold number three, had ordered the ship grounded.

The <u>M/V Sumner Knight</u> was assisting in firefighting operations, and the fire appeared to be coming under control. The weather was overcast with easterly winds 11-16 knots. No assistance from the Coast Guard was requested, but the <u>Key Biscayne</u> was advised to check in with the Coast Guard every half-hour or so. The pilot also provided the name of the ship's agents, Nordkelt, Inc.

COTP next contacted Nordkelt. Mr. Dillahay of that firm reported that the cargo on the <u>Key Biscayne</u> included calcium carbide and tetraethyl lead. Mr. Dillahay was asked to produce the stowage plan.

At about 1315 the stowage plan was delivered to COTP NOLA. It was quickly determined that hold number three contained 680 drums of calcium carbide. The tetraethyl lead, approximately eight tons, was stowed on the starboard side of the vessel's fo'c'sle on deck.

This case, adapted from an actual situation, was written by Arthur D. Little, Inc., for the U.S. Coast Guard to be used in training. Actual names, places, and dates have been changed. The case was written for class discussion rather than to illustrate effective or ineffective administration.

AD-A034 655 LITTLE (ARTHUR D) INC CAMBRIDGE MASS F/G 5/2
DEVELOPMENT OF CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM (CH--ETC(U)
OCT 76 D S ALLAN, G H HARRIS DOT-CG-24655-A
UNCLASSIFIED ADL-C-74685 USCG-D-117-76 NL

2 OF 3
AD
A034655

SIFIED

2 OF 3

AD
A034655

1.0 4.5 5.0 5.6 6.3 7.1 8.0 2.8 3.2 3.6 4.0 2.5 2.2 2.0

1.1 1.8

1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

who actually designed the original CHRIS concept and by others who contributed to the development of specific components of the system.

An understanding of the depth and range of problems CHRIS could help solve was developed; CHRIS elements were reviewed so as to decide which were the most difficult to understand; and prior skills that would be needed by students so as to be able to use and understand CHRIS were considered. Other systems that Coast Guard personnel used which might be as complex as CHRIS such as navigation and piloting were also reviewed. From this analysis, the skills that must be learned by Coast Guard personnel in order to use CHRIS effectively were established.

- Course Design - From the above assessment, the order in which skills and tasks would be used in applying CHRIS were determined. The subject matter was then divided and sequenced and each training element was weighted as to its importance and complexity so as to specify the amount of time to be devoted to each component of the program.

- Material Development - The next step was to produce the classroom material for each of the courses and to make it parallel (and simulate) the activities participants would perform in the field. Even the non-user presentations to describe how the system would be used was illustrated by a "case" example. The problem cases for all the courses were based, as often as possible, on actual reported incidents and were linked to briefings and notes.

Three major considerations became obvious as the development of the CHRIS training program proceeded:

- In the MEP course at Yorktown at least four days of classroom work with nights available for preparation are needed for personnel to become proficient users of CHRIS. Also, active practice after that training period is needed to maintain competency. Therefore, Strike Team training should concentrate on reviewing CHRIS with field personnel after they have gone through MEP training at Yorktown.

- Personnel who use CHRIS should have certain basic mathematical skills encompassing such subjects as exponential expressions of large and small numbers, logarithmetic scales, and graphical displays. These skills need to be taught before actual training in the application of CHRIS begins.
- In the absence of Strike Team review training, personnel must practice on their own with the CHRIS problem book. The Coast Guard should find ways to require or encourage personnel to practice with CHRIS in order to maintain a high level of proficiency.

5.3 Conclusions and Recommendations

The following conclusions and recommendations relate to the CHRIS training program:

(1) The facility with which instructors and students proceeded through their CHRIS lessons tended to confirm that CHRIS itself has been designed so that the content and presentation correlates well with the needs and abilities of potential users of the system.

(2) The observed interest and enthusiasm shown by both instructors and students along with the level of knowledge of CHRIS that was achieved in the early training sessions, has demonstrated that the design of the training program has been very effective.

(3) A particularly important observation made as a result of the implementation of the training program is that CHRIS itself is a powerful training tool for educating Coast Guard personnel in many aspects of response methodology and in doing so exceeds the original objectives of the system involving an information base for emergency response to chemical discharges.

(4) CHRIS practice sessions at Yorktown and Strike Team training sessions can provide valuable information on revisions and additions that might be made to increase the utility of CHRIS. Full advantage of this resource should be taken during the CHRIS utilization study.

(5) Provision should be made to modify and update the training programs and associated training programs and associated training aids as

more is learned about the use of CHRIS during actual emergency situations (as for example, during the utilization study) and as CHRIS itself is revised and updated.

(6) A programmed instruction, self-paced training package for CHRIS should be developed. This training aid would enable Coast Guard personnel to either teach themselves how to utilize CHRIS or review the use of specific components of CHRIS, selecting a depth, breadth, and frequency of training most appropriate to individual interests. A training package of this type would complement the group training at Yorktown and the periodic Strike Team training.

6.0 OTHER CHRIS-RELATED STUDIES

6.1 Chemical Hazards Response Information System for Multimodal Accidents (CHRISMA)

This study[7] examined the need for improved technical and other information for meeting emergencies connected with the transportation of hazardous materials, particularly actual or potential chemical discharges, regardless of mode. The Chemical Hazards Response Information System (CHRIS), under development by the United States Coast Guard to furnish in-depth guidance during emergencies involving waterborne transport, was seen as a likely prototype for other modes as well. Accordingly, a reevaluation of CHRIS has been conducted to determine the desirability of enlarging its scope to encompass all modes of transportation. It is concluded that the expanded system would indeed be beneficial in reducing losses to life, property, and the environment. Necessary modifications to CHRIS are conceptually quite modest in nature. The information system would be composed of a decentralized organization providing response guidance on request to local emergency services personnel, a computerized hazard assessment system operated at Headquarters, and three reference manuals furnished to all response organizations.

A pretest of the basic system components and services before full-scale development is recommended in view of several potential difficulties:

- The anticipated low frequency of need per user installation;
- The very short response time available for effective action; and
- The large number of disparate, autonomous emergency response personnel who do not operate within a defined regional or national organization or communications system.

6.2 A Survey Study to Select a Limited Number of Hazardous Materials to Define Amelioration Requirements

This study[8] was directed toward the foundation of a planned research and development (R&D) program which, when initiated on a priority basis, would result in a significantly improved capability to ameliorate spills of hazardous chemicals. Once available, the amelioration equipment would provide the U. S. Coast Guard (USCG) On-Scene Coordinator (OSC) with an inventory of response equipment and systems that would permit effective countermeasure action against accidental discharges of hazardous chemicals into waterbodies.

The work entailed the categorization of hazardous chemicals according to physical and chemical characteristics that were perceived to be amenable and important to the development of amelioration techniques. A total of 400 hazardous chemicals deemed to encompass most of the more critical chemicals in terms of quantity shipped and the severity of the hazards presented were associated with each of approximately 30 amelioration categories. A representative chemical was then selected for each category with the intent that it would provide the basis for searching for, evaluating, and developing amelioration methods for each category. The representative chemicals were chosen by assessing the chemical and physical behavior of the chemicals, their risk indices, and other practical considerations.

Existing response (amelioration) equipment and systems were then reviewed to determine applicability to each representative chemical and its associated category. Once gaps and deficiencies were determined, conceptual response studies were initiated that resulted in a number of potential amelioration techniques that were considered to warrant USCG-sponsored research and development efforts.

Simultaneously, investigations were made into completed and on-going R&D studies in the governmental and industrial sectors to determine which

studies could benefit USCG amelioration needs. Near-term usable research is recommended, and areas in which joint research (USCG and others) might expedite an amelioration solution were cited.

From the entire investigation, a reasonable and comprehensive basis for searching for and evaluating new and improved amelioration techniques has been developed.

6.3 Inventory of Equipment and Agents for Responding to Marine Transportation Fires[9]

The objective of this program was to review the state-of-the-art of fire-fighting techniques and equipment that the United States Coast Guard may utilize in responding to fires involving hazardous cargoes in marine transportation. An inventory of pertinent fire-fighting, de-watering and personal protection equipment and comercially available fire extinguishing agents was to be prepared, keeping in mind the characteristics of fires that may occur on board chemical cargo vessels and the present response capabilities of the USCG. Novel devices or ideas for responding to marine transportation fires which are either under development or which appear to be feasible but require developmental work were to be identified where possible.

Information relating to the characterization of marine transportation fires was gathered from USCG descriptions of typical fires that have occurred in the past few years. Present USCG response capabilities were obtained through contacts with several Coast Guard personnel and through visits to the USCG Boston port facilities and Cape Cod air station. Manufacturers of equipment and materials in the following categories were asked to provide a list of pertinent equipment or materials, and, where applicable, the model number, capabilities, limitations, weight and volume penalties, power requirements and catalog price:

Extinguishing agents: Dry chemicals, foams (protein, alcohol high expansion, aqueous film forming), halons (1211, 1301), inerting gases (carbon dioxide, nitrogen), inert dry powders, and water additives.

Extinguishing equipment: Wheeled and skid-mounted units; foam generators, eductors, and proportioners; water and foam nozzles; monitors; and water pumps.

Life support equipment: Self-contained breathing apparatus, protective clothing, portable gas detector (oxygen, carbon monoxide, flammable gases) and radiation monitors.

Dewatering systems: Eductors and submerged pumps.

Several Government agencies involved in research and development of fire-fighting systems that may satisfy USCG requirements were contacted or visited. These agencies included U. S. Naval Laboratory, Office of Naval Materials, Office of Ocean Engineering - NAVSHIPS, Naval Ship Engineering Center, U. S. Army Mobility Equipment Research and Development Center - Fort Belvoir, and the U. S. Forest Service - Equipment Development Center. In addition, selected manufacturers of firefighting helicopters and helicopter-borne fire extinguishing equipment were contacted. The Boston Fire Department was queried about the use of its fire boats, and its recently acquired fire boat was visited. Finally, literature relating to response to marine transportation fires was examined.

REFERENCES

1. Allan, D. W., G. H. Harris, G. R. Schimke, and R. W. Neal, "Preliminary System Development Chemical Hazards Response Information System," Final Report 73096-1, Arthur D. Little, Inc., for U. S. Coast Guard, May 1972 (NTIS AD 757-473) and Appendices I-VI (NTIS AD 757-472).

2. "MCA Cargo Information Card Manual for Bulk Dangerous Cargoes," Manufacturing Chemists Association, Inc., Washington, D. C., 1970.

3. "Chemical Safety Data Sheets," Chemical Section, National Safety Council, Chicago, Illinois.

4. Reid, R. C. and T. K. Sherwood, "The Properties of Gases and Liquids," McGraw Hill, 1958.

5. "System for Evaluation of the Hazards of Bulk Water Transportation of Industrial Chemicals," Committee on Hazarouds Materials, National Academy of Sciences, National Research Council, February 1974.

6. Arthur D. Little, Inc., "Hazard Assessment Computer System (HACS)--User Manual," prepared for U. S. Coast Guard, Contract No. DOT-CG-24, 655-A, December 1974.

7. Arthur D. Little, Inc., "Chemical Hazards Response Information System for Multimodal Accidents (CHRISMA)," prepared for U. S. Coast Guard, Contract No. DOT-CG-24, 655-A, April 1975 (NTIS AD-16296).

8. Lyman, W. J., et al., "Survey Study to Select a Limited Number of Hazardous Materials to Define Amelioration Requirements," Final Report by Arthur D. Little, Inc., Report No. CG-D-46-75, Task 4400.1, U. S. Coast Guard, March 1975.

9. Atallah, S., et al., "Inventory of Equipment and Agents for Responding to Marine Transportation Fires," Arthur D. Little, Inc., Final Report, U. S. Coast Guard, Contract No. DOT-CG-24, 655-A, January 1974.

APPENDIX A

Schedule of Initiation and Completion of Major CHRIS Components

APPENDIX A

Schedule of Initiation and Completion of Major CHRIS Components

	Date
Condensed Guide to Chemical Hazards, CG-446-1	
Effective contract date	26 June 72
Approvals	
Phraseology	16 August 73
Proposed text	7 November 73
Camera-ready copy	February 74
Hazardous Chemical Data, CG-446-2	
Effective contract date	26 June 72
Approvals	
Data sources	16 November 73
Illustrative data sheets	16 August 73
Explanation of terms	16 November 73
Proposed text	7 November 73
Report on data gaps (draft)	16 November 73
Camera-ready copy	2 January 75
Hazard Assessment Handbook, CG-446-3	
Effective contract date	26 June 72
Approvals	
Camera-ready copy	14 March 74
Report on assessment models in support of Hazard Assessment Handbook	14 March 74
Response Methods Handbook, CG-446-4	
Effective contract date	12 December 72
Approvals	
Camera-ready copy	12 February 1975

Schedule of Initiation and Completion of

Major CHRIS Components

Continued

	Date
Hazard Assessment Computer System (HACS)	
Effective contract date (HACS)	26 June 72
Effective contract date (Physical Properties File)	14 May 73
System installation complete	1 April 75
Submittal of draft User's Mnaual	December 74
Cover design for all manuals approved	16 November 73
Task Criteria	
Final report - approved	31 May 74
Regional Contingency Plan Data Base	
Effective contract date (Pilot Model and Development Plan)	20 October 72
Approval of Pilot Model and Development Plan	14 March 74
CHRIS Training Program	
Effective contract date (MEP)	25 October 73
Effective contract date (non-user & strike team training packages)	28 June 74
Non-User's Presentation (approved)	2 January 75
Remainder of Training Program approval	-
Chemical Hazards Response Information System for Multi-Model Accidents (CHRISMA)	
Effective contract date	26 June 72
Approval of draft report	16 November 73
Inventory of Equipment and Agents for Responding to Marine Transportation Fires	
Effective contract date	14 November 73
Approval of draft report	14 May 74

Schedule of Initiation and Completion of

Major CHRIS Components

Continued

	Date
A Survey Study to Select a Limited Number of Hazardous Materials in Order to Define Amelioration Requirements	
Effective contract date	24 May 73
Approval	
Camera-ready copy	16 December 74

APPENDIX B

Supporting Information for CG-446-2, Hazardous Chemical Data

APPENDIX B-I

Preparation of Temperature Plots

Where applicable or appropriate, temperature-dependent compound properties are described by a series of up to eight plots or graphs for each compound. Each temperature function is represented in equation form, defined in Table B-I-1, where the coefficients in each equation are determined for each compound using estimation equations or regression on experimental data. Graphs produced for Manual II are prepared using the units as shown in Table B-I-1 for each function; in most cases, however, it is more convenient during data collection to express property values, coefficients, and temperature ranges in alternate units. Temperatures and function values generated by the equations can either be converted to the desired units or the equations as given in Table B-I-1 can be transformed to equivalent expressions in which the temperature and coefficients are converted to produce function values in the desired units. A consistent approach is preferred in which all units are expressed such that the form of the equation is unchanged.

Plots prepared for inclusion in Manual II are formatted with standard axis labels, and arranged on two pages (four frames each page) for each chemical (refer to Manual II). Where data have not been provided (not applicable, not pertinent, etc.), only a title for the particular plot is produced and a descriptive explanation is entered independently. In addition to the logic necessary to evaluate each of the expressions shown in Table B-I-1, limits for the range of each plot are computed.

The specific procedures which are followed to prepare the plots of temperature-dependent properties will include, as necessary, units conversion, the preparation of input data for use with suitable plotting software, editing and validation of all input data and the actual execution of plot production runs.

Existing plots of temperature-dependent behavior have been previously prepared in a manner associated with the collection and preparation of chemical-specific data for use with the Hazard Assessment Computer System (HACS). These procedures are described in the following paragraphs to identify the availability of existing related computer programs operating on the CDC 3300 Computer System at Coast Guard headquarters; however, as a result of file structure and data units conventions of HACS, these procedures involve additional data manipulations and conversions not specifically required for the preparation of temperature function plots.

1. Temperature function data points (temperature and function value at that temperature) where given, equation coefficients and temperature bounds are obtained and recorded on source data collection sheets, together with additional notes describing the compound behavior

including references to data which has not been supplied (e.g., not pertinent, not available).

2. For each chemical, data elements required for the plots are obtained from the source data collection sheets. Depending on the format of these sheets, it may be necessary to transcribe the data to a form suitable for keypunching. At a minimum, the data recorded will include all specified temperature function coefficients, range of temperature for which the function applies, chemical recognition code and additional data required to evaluate the expressions in Table B-I-1, (e.g., molecular weight, units specification). Associated with each data item prepared for keypunching are a status code, indicating for each item whether the value is missing, estimated or exact, a field number referencing the location of the item in a chemical record, and a transaction type indicator (add, change, delete). All individual field entries are coded as change transactions.

   For the purpose of recording chemical data on the physical properties data base referenced by the Hazard Assessment Computer System (HACS), additional physical properties and data are obtained for each chemical and included with the data elements describing temperature-dependent behavior. The physical properties data base contains data values for up to 74 fields (properties or descriptions) for each chemical, and associated with each of these fields is a status code (missing, exact, estimate).

3. Updating of the physical properties data base is accomplished through the use of an update program operating on the CDC 3300 at Coast Guard Headquarters. The update program (written in FORTRAN IV) accepts input data for a chemical, permitting the addition of data for new chemicals to the file, or the revision of existing data. Extensive input data editing features are included in this program, and a fixed-length binary output record is generated for each chemical, giving the status codes and values for all 74 fields.

   All data on the physical properties file are recorded in pre-defined SI (System International) units, and standard input to the update program must be entered in SI units. Limited conversion capabilities are in the process of being installed; however, depending on the units used for source data collection, a pre-processing step may be necessary for conversion of source data to suitable units for use with the update program.

4. Given an updated physical properties file, temperature function data for any chemical can be retrieved and re-formatted as necessary for use as input to any suitable plotting software. Existing programs

are available at Coast Guard Headquarters for conversion (binary to BCD) of tape files.

TABLE B-I-1

TEMPERATURE FUNCTIONS

1. Saturated Liquid Density,

$$LD = (ARHO) + (BRHO)t + (CRHO)t^2$$

$$t_{LO} < t < t_{UP}$$

where LD = saturated liquid density in LB/CU-FT

$ARHO$ = coefficient

$BRHO$ = coefficient

$CRHO$ = coefficient

t = temperature in °F

t_{LO} = lower bound of temperature range in °F

t_{UP} = upper bound of temperature range in °F

2. Liquid Heat Capacity,

$$C_p = (AHC) + (BHC)t$$

$$t_{LO} < t < t_{UP}$$

where C_p = liquid heat capacity in BTU/LB-F

AHC = coefficient

BHC = coefficient

t = temperature in °F

t_{LO} = lower bound of temperature range in °F

t_{UP} = upper bound of temperature in °F

3. Liquid Thermal Conductivity,

$\lambda = (ACON) + (BCON)t$

$t_{LO} < t < t_{UP}$

where λ = liquid thermal conductivity in BTU/HR-FT-F

ACON = coefficient

BCON = coefficient

t = temperature in °F

t_{LO} = lower bound of temperature range in °F

t_{UP} = upper bound of temperature range in °F

4. Liquid Viscosity,

$\ln \mu = (AVIS) + (BVIS)/t$

$t_{LO} < t < t_{UP}$

where μ = liquid viscosity in centipoise

AVIS = coefficient

BVIS = coefficient

t = temperature in °F

t_{LO} = lower bound of temperature range in °F

t_{UP} = upper bound of temperature range in °F

5. Solubility in Water,

$S = (A) + (B)t$

$0°C < t < 30°C$

where S = solubility in LB/100 lb. water

A = coefficient

B = coefficient

t = temperature in °F

6. Saturated Vapor Pressure,

$\log_{10} P_{vp} = (AVP) - (BVP)/[(CVP) + t]$

$t_{LO} < t < t_{UP}$

where P_{vp} = saturated vapor pressure in PSIA, plotted on a logarithmic scale

AVP = coefficient

BVP = coefficient

CVP = coefficient

t = temperature in °F

t_{LO} = lower bound of temperature range in °F

t_{UP} = upper bound of temperature range in °F

7. Saturated Vapor Density,

$P = P_{vp} \cdot M/RT$

where P = saturated vapor density plotted on a logarithmic scale in LB/CU-FT as a function of temperature in °F

P_{vp} = saturated vapor pressure

M = molecular weight

R = gas constant

T = saturation temperature

Table B-I-1 Continued

8. **Ideal Gas Heat Capacity,**

$$C_p = (AVCP) + (BVCP)t + (CVCP)t^2 + (DVCP)t^3$$

$$t_{LO} < t < t_{UP}$$

where C_p = ideal gas heat capacity in BTU/LB-F

AVCP = coefficient

BVCP = coefficient

CVCP = coefficient

DVCP = coefficient

t = temperature in °F

t_{LO} = lower bound of temperature range in °F

t_{UP} = upper bound of temperature range in °F

APPENDIX B-II

Hazard Assessment Codes (Data Item 11)

Introduction

A chemical released into the environment will interact with its surroundings in a manner which reflects its physical and chemical properties. Liquid chemicals which have boiling points less than the ambient temperature and which are insoluble and less dense than water will, for example, immediately begin to boil when discharged onto water and continue to do so until completely vaporized.

Substances which are soluble in water and which have high boiling points, however, will obviously behave quite differently. When spilled onto water, they can be expected to mix with the water and become dispersed within the water body.

In the first case above, the chemical initially may present a pool fire hazard, and as it boils off, a flammable or toxic vapor cloud hazard. The circumstances in the second case indicate again that the initial hazard might involve a pool fire, but that any subsequent hazards are as a result of water pollution. These examples illustrate the actions of but two types of chemicals which behave differently because of their properties. Within CHRIS are included many other types, each with its own behavior peculiarities and associated hazards.

The Hazard Assessment Tree

To allow estimations of the hazards for a variety of chemical types in a systematic manner, a "Hazard Assessment Tree: Events Chart" was developed. This "tree" is presented in Figure 3 of the main text and may be thought of as the "index" for both the Hazard Assessment Handbook (CG-446-3) and the Hazard Assessment Computer System (HACS). Each branch (or path) of the tree represents an assessment procedure which describes the behavior of a particular type of chemical under a given set of accident conditions. The rectangular blocks to be found within each branch represent actions which the chemical will, or may take, and which require mathematical estimation of rate, quantity, distance, concentration, etc., for a complete hazard assessment. These blocks are individually lettered and correspond to generalized

mathematical models around which the handbook and computer system are built.

Hazard Assessment Codes

During the development of CHRIS, it was deemed advantageous to give the user an indication of which branches of the tree were applicable to any particular chemical. This not only would minimize the time required of a user to perform a hazard assessment, but also would help ensure that a user would not misinterpret instructions and utilize the wrong set of mathematical models. This perceived need was fulfilled by the development of what has been termed "hazard assessment codes."

The hazard assessment code for a particular chemical is simply a set of letters which describes the branches of the tree and thereby the mathematical models applicable to the chemical. For example, the letters in the hazard assessment code ABCDEFG indicate the following:

A: Model A is the venting rate model for liquids and gases. Inclusion of this model code indicates the user may utilize this model to estimate the quantity, rate, and time of discharge from a punctured tank.

B: Model B is the "flame jet" model. Its inclusion indicates the substance is flammable, has a boiling point less than ambient, and may be released in gaseous form under pressure from a hole in a tank. The model can be utilized to estimate the length and diameter of the flame and the thermal radiation flux level at a user specified distance.

C: Model C is the vapor dispersion model for discharge of a gas from a ruptured tank. It also indicates that the substance has a boiling point less than the ambient temperature and can be utilized to estimate the downwind distances over which the gas cloud released can present a toxicity or flammability hazard.

D: This model and subsequent models E, F, and G are applicable, as above, to substances with a boiling point less than ambient with the additional conditions that the chemical can be transported as a liquefied compressed gas or a liquefied gas (by refrigeration), is insoluble in water, and has a liquid density less than that of water. Model D in particular is used to estimate the size of the spill pool if an amount of the chemical should be discharged onto water and to estimate the time it will take for all of the floating, boiling substance to vaporize.

E: Model E estimates the flame height and thermal radiation level from the pool described in Model D if it should be ignited before it vaporizes. Its inclusion, like Model B, also indicates the substance is flammable.

F: Model F does not exist as a separate model in the handbook or computer system because, for simplification, its function was incorporated into Model D. Nevertheless, as presented in the tree, it indicates that if the pool described by Model D did not ignite, one would wish to know the boiling rate, i.e., the vapor evolution rate, of the pool for input to Model G.

G: Like Model C, this model is a vapor dispersion model. Its function is to estimate hazard extents from a vapor cloud being generated from a boiling, floating pool.

Assignment of these codes to chemicals requires that guidelines be established as to what constitutes an insoluble or soluble chemical, a volatile or nonvolatile chemical, etc. These guidelines are described in the following:

Soluble: A substance with a solubility in water of >5% is to be considered soluble. It will dissolve into a large body of water in a reasonably short period of time.

Insoluble: A chemical with a solubility in water of 0-1%. For the purposes of hazard evaluation, little, if any, of the substance will become dispersed in the water body.

Soluble and Insoluble: A substance with a solubility in water between 1 and 5%. It may or may not, depending upon the environmental conditions, dissolve into water in significant amounts.

Ambient Temperature: Eighty degrees F (80° F) is the temperature utilized to determine whether or not a substance can boil below ambient temperature at 1 atm pressure. Thus, a substance with a normal boiling point (bp) less than 80°F will be considered to boil below ambient temperature and vice versa.

Heavier-than-Water: A substance with a specific gravity >1.1 is considered to always sink in water.

Lighter-than-Water: A substance with a specific gravity <0.98 is considered to always float in water.

Heavier-or Lighter-than-Water: A substance with a specific gravity between 0.98 and 1.1 may either float or sink in water depending upon the environmental conditions.

Volatile: A substance which has a normal boiling point (bp) greater than 80°F but less than 212°F is considered to be volatile. Exceptions, however, may be required for certain chemicals on a case by case basis.

Reacts with Water: A substance which chemically interacts with water.

Self-Reacting: A substance which can spontaneously react when released into the environment. For example, a pyrophoric substance.

Once the above quidelines have been utilized to determine the characteristics of the substance, Table B-II-1, the Code Selection Matrix, is entered to determine which model codes are appropriate for the substance. To be noted is that selection of a particular model code only requires that the checked conditions for that code be satisfied. Where, because of its properties, a substance must be considered both soluble or insoluble, or both heavier- or lighter-than-water, all codes applicable to both conditions should be selected.

The hazard assessment code is then formed, with a single exception, by listing the individual model codes in alphabetical order. This exception and other exceptions to the procedure are described below.

Exceptions and Clarifications

Strict adherence to the above guidelines can in some instances lead to unwieldy or confusing codes which are unnecessary from a hazard assessment viewpoint. To avoid this occurrence, the following exceptions and clarifications are made:

1. A liquid which reacts rapidly with water need only be assigned the code A0 or AC0 (if bp < ambient). Only if it reacts at a reasonable rate and not virtually instantaneously should it be assigned the codes it would have if it did not react and the code 0. Similar considerations apply when the code Z is assigned. In both cases, the code 0 or Z should be the last code in the sequence. When a substance reacts so slowly with itself or water that it is felt specification of 0 or Z might lead to a misinterpretation of the hazards of the chemical, consideration should be given to deletion of the reactive code.

2. If an insoluble chemical with a boiling point less than ambient must be considered to both float and sink, assume that it floats. This will have the disadvantage that the downwind hazard extent predicted will be slightly smaller but will have the greater advantage that the flame size and thermal radiation hazards can be conservatively evaluated.

TABLE B-II-1

CODE SELECTION MATRIX

(bp = normal boiling point)

	Liquid or gas	Solid	Flammable	Soluble	Insoluble	bp > 80°F	bp < 80°F	bp < 212°F	Lighter-than-water	Heavier-than-water	Reacts with water	Self-reacting
A	X											
B	X		X				X					
C	X						X					
D	X				X		X		X			
E	X		X				X		X			
F	X						X		X			
G	X						X		X			
H	X		X		X		X			X		
I	X				X		X			X		
J	X				X		X			X		
K	X			X			X					
L	X		X	X			X					
M	X			X			X					
N	X			X			X					
O	X										X	
P	X			X		X						
Q	X		X	X		X						
R	X			X		X		X				
S	X			X		X		X				
T	X				X	X			X			
U	X		X		X	X			X			
V	X				X	X		X	X			
W	X				X	X		X	X			
X	X				X	X				X		
Y	X		X		X	X				X		
Z												X
SS		X		X								
II		X			X							
RR		X									X	

3. If a chemical with boiling point less than ambient must be considered both soluble and insoluble, it is to be assumed soluble. The soluble path fully includes all the hazards which the insoluble path would give in addition to the water pollution evaluations.

4. If a volatile material with boiling point greater than ambient must be considered to be both insoluble and soluble, it is to be assumed insoluble in regards to vapor dispersion hazards and both soluble and insoluble in regard to water pollution hazards. This means that a code such as APQRSTUVW would be shown as APQTUVW. This combination will give the most conservative answers for each of the possible actions of the chemical. This is felt to be appropriate in view of the fact that one does not a priori know how the chemical will act in this situation.

Other Considerations

The procedure outlined has the effect of "tailoring" the hazard assessment codes to the manner in which the Hazard Assessment Handbook functions. This is intentional in that it is expected that the users of HACS will have a greater knowledge and appreciation of the subject and will eventually use the code only as a guideline in their decision-making process. It is important that this fact be given proper consideration for it will in some cases be found necessary to specify a hazard assessment code best suited to the function of the handbook which does not entirely point out all models which might be given consideration for HACS use. This latter statement is also meant to imply that the individual assigning the codes must be thoroughly familiar not only with the properties of the chemicals, but also with the manners in which both the handbook and HACS can be used to evaluate chemical hazards.

APPENDIX B-III

Chemical Recognition Codes

Each chemical in CHRIS is assigned a unique three-letter chemical recognition code such as "HMT" for hexamethylene tetramine and "EPA" for 2-ethyl-3-propylacrolein. These codes appear in the top corners of the chemical data sheets in both CG-446-1 and CG-446-2, and are used as a simple abbreviation of chemical names. Their primary and originally intended function is to insure that the complicated name of some compound is not misunderstood under conditions of difficult radio communications. They have, however, also b-en found useful for specifying and identifying chemicals in HACS and elsewhere in the system.

Conceptualization of the form of the codes included considerations of the minimum number of letters necessary to provide one unique code for each chemical, and how and whether the code should be related to the "appearance" of the chemical name.

Given the desire that the first letter of the code should always be the same as that of the name of the chemical for alphabetization and recognition purposes, the decision was made that a total of three letters would be sufficient. This allows a total of 676 (26 x 26) unique codes for each letter of the alphabet when the first letter of the code is fixed.

It was also decided that the second and third letters of each code in some way, where possible, be related to the chemical name; again, for purposes of recognition and confirmation of correct use. Thus, these codes were by no means assigned arbitrarily, but rather, by the utilization of definite guidelines. These guidelines are presented below in order of their perceived ability to generate an acceptable and unique code for a chemical name.

1. The first letter of any three-letter code should be the same as the first letter of the chemical name.
2. Where the compound is an element and the chemical symbol for the element satisfies guideline 1 above, the symbol should be used followed by the letter X to fill blanks. Thus, fluorine would have the code

FXX, chlorine would have CLX, and bromine, the code BRX.

3. If the chemical already has a commonly recognized three-letter abbreviation which satisfies guideline 1 above, this code should be used as it is likely to appear on shipping papers, stenciled on drums, etc. TDI, DDT, MEK, LNG, LPG, and TOL are examples of such abbreviations.

4. The first letters of major chemical groups or designations are appropriate. For example, AminoEthanolAmine can be AEA and CycloHexylAmine can be CHA.

5. If the chemical has three words, the first letter of each may be used; e.g., EHT for ethyl hexyl tallate. If it has more than three words, one may use the first three words, or if necessary, the first, second, and fourth, or the first, third, and fourth, etc. EGM is thus used for ethylene glycol monobutyl ether, while EGE is used for ethylene glycol monoethyl ether.

6. Combinations of the first letters of syllables of the word or words in the name can be chosen in the same manner as the first letters of words as outlined in guideline 5. Thus, DDC is used for 1-Dodecene and ANL for aniline. It is often desirable in such cases to divide the word into syllables which are more commonly identifiable than those which are grammatically correct. An example is ac-e-tone which became a-ce-tone, and hence, ACT instead of AET.

7. In cases where the word has only two syllables, the first letter of the word and the first two letters of the second syllable or vice versa can be used. It is preferred that if one of the syllables starts with two consonants, they should appear in the code. Examples are ETH for ethane and ALD for aldrin.

8. If the name is a single word, the first three letters

might be used. BUT is recognizable for butane and CUM for cumene.

9. When the name has a prefix such as iso- or n-, the first letter of the prefix, when used as the last letter of the code, will often produce a unique code such as BAN for n-butyl alcohol, BAS for sec- butyl alcohol, and BAT for tert- butyl alcohol.

10. Sometimes the first and last letter of a syllable coupled with the first letter of another syllable will produce a unique and recognizable code. Examples include BNZ for benzene, HPT for heptane, HXA for hexane, and HXE for 1-hexene.

These guidelines are capable of producing numerous possible codes for every chemical name and were usually sufficient to evolve at least one which was unique for each chemical. However, if and when the number of chemicals in CHRIS increases, it may, and very probably will, become necessary that reasonable judgment be used in extending and combining the guidelines to produce codes which are not duplicates of others.

APPENDIX B-IV

Data Sources

The source of every item of data contained in the Manual is recorded in master data files and is available on request. The purpose of this section is to list the sources from which was obtained the major portion of data recorded. Many other sources were used; because most of them were used for only a few items, they are not given here. In a few cases the value, procedure, or equipment given is based on an analogy with that for a closely related compound. The analogy was drawn by an expert in the field, whose identity appears in the master data file.

Where a source was used for a single category of data, the source is given in the Explanation of Terms section of the Manual and is not repeated here.

A. General Sources - These sources contained data for many of the 13 data categories used:

1. Manufacturer's Technical Bulletins - These are usually the best single source of general information about the compound. All bulletins were solicited in late 1972 and contain the most up-to-date data. Bulletins were not available for a few compounds that are not items of commerce, but are intermediates shipped from one manufacturing site to another.

2. Material Safety Data Sheets - These were provided by the manufacturer using the U. S. Department of Labor Form OSHA-20 or an approved modification.

3. Code of Federal Regulations - Office of the Federal Register, Archives and Record Service, Washington, D. C., 1972. Titles 46 (Shipping) and 49 (Transportation) were used in the most recent revision available, in all cases since January 1, 1971.

4. Chemical Safety Data Sheets - Manufacturing Chemist Association, Washington, D. C.

5. Industrial Safety Data Sheets - National Safety Council, Chicago, Illinois.

6. International Maritime Dangerous Goods Code - Inter-Governmental Maritime Consultative Organization (IMCO), London, 1972.

7. Petroleum Products Handbook - V. B. Guthrie (edit.), McGraw-Hill, New York, 1960.

8. Glossary of Terms Used in Petroleum Refining - American Petroleum Institute, New York, 1962, 2nd edition.

9. The Handling and Storage of Liquid Propellants - Office of Defense Research and Engineering, U. S. Government Printing Office, Washington, D. C., 1963.

10. Industrial Chemicals - W. L. Faith, D. B. Keyes, and R. L. Clark, Wiley, New York, 1965, 3rd edition.

11. Chemical Technology of Petroleum - W. A. Gruse and D. R. Stevens, McGraw-Hill, New York, 1960, 3rd edition.

12. Chemical Rocket/Propellant Hazards - CPIA Publication No. 194, Vol. III, 1970.

13. Organic Solvents - J. A. Riddick and W. B. Bunger, Wiley-Interscience, New York, 1970, 3rd edition.

14. Transport of Dangerous Goods - United Nations, New York, 1970 (4 vols).

15. Kirk-Othmer Encyclopedia of Chemical Technology - Interscience-Wiley, New York, 1st edition (1947-1960); 2nd edition (1963-1970).

16. Evaluation of the Hazard of Bulk Water Transportation of Industrial Chemicals, A Tentative Guide - National Academy of Sciences, Washington, D. C., 1970; includes supplement with additions to March 1972.

B. Chemical Designations

1. Commercial Organic Chemical Names - Compiled by the Synthetic Organic Chemical Manufacturers Association (SOCMA), Chemical Abstracts Service, Columbus, Ohio, 1965.

2. Chemical Synonyms and Trade Names - W. Gardner and E. I. Cooke, CRC Press, Cleveland, Ohio, 1971, 7th edition.

3. The Merck Index of Chemical and Drugs - Merck and Co., Rahway, New Jersey, 1968, 8th edition.

C. Health Hazards

1. Industrial Hygiene and Toxicology - F. A. Patty, Interscience, New York, 1963, 2nd edition, Vol. II.

2. Toxicity and Metabolism of Industrial Solvents - E. Browning, Elsevier, New York, 1965.

3. Practical Toxicology of Plastics - R. Lefaux, CRC Press, Cleveland, Ohio, 1968.

4. Industrial Toxicology - L. T. Fairhall, Williams and Wilkins, Baltimore, Maryland, 1957, 2nd edition.

5. Toxicology of Drugs and Chemicals - W. B. Deichmann and H. W. Girarde, Academic Press, New York, 1969.

6. Clinical Toxicology of Commercial Products - M. N. Gleason, et al., Williams and Wilkins, Baltimore, Maryland, 1969, 3rd edition.

7. Handbook of Toxicology. Acute Toxicities of Solids, Liquids and Gases to Laboratory Animals - W. S. Spector, Saunders, Philadelphia, Pa., 1956.

8. Occupational Diseases. A Guide to Their Recognition - U. S. Department of Health, Education, and Welfare. Public Health Service Publication No. 1097. Superintendent of Documents, Washington, D. C., 1964.

9. First Aid Textbook - American National Red Cross, Washington, D. C., 1972.

10. Electrical Safety Practice-Odor Warning for Safety - Instrument Society of America (ISA), Pittsburgh, Pa., 1972, Monograph 113.

11. Toxic Substances - Annual List 1971 - H. E. Christensen, U. S. Department of Health, Education and Welfare, Superintendent of Documents, Washington, D. C., 1971.

D. Fire Hazards

1. The Fire and Explosion Hazards of Commercial Oils - W. Vlachos and C. A. Vlachos, Vlachos and Co., Philadelphia, Pa. 1921.

2. 1972 Annual Book of ASTM Standards - American Society for Testing and Materials, Philadelphia, Pa., 1972.

3. Fire Protection Guide on Hazardous Materials - National Fire Protection Association (NFPA), Boston, Mass., 1972, 4th edition, Nos. 325A, 325M, 49, 491M, and 704M.

4. Fire Protection Handbook - G. H. Tryon (edit.), National Fire Protection Association (NFPA), Boston, Mass., 1969, 13th edition.

5. Handbook of Industrial Loss Prevention - Factory Mutual Engineering Corp., McGraw-Hill, New York, 1967, 2nd edition.

E. Water Pollution

1. Water Quality Criteria Data Book - United States Environmental Protection Administration, Superintendent of Documents, Washington, D. C., 1970, Vol. 1 - Organic Chemicals; 1971, Vol. 2 - Inorganic Chemicals.

2. Engineering Management of Water Quality - P. H. McGauley, McGraw-Hill, New York, 1968.

3. The BOD of Textile Chemicals - Proceedings of the American Association of Textile Chemists and Colorists, American Dyestuff Reporter, August 29, 1966, p. 39.

4. *Biodegradable Surfactants for the Textile Industry* - American Dyestuff Reporter, January 30, 1967.

5. *Water Quality Criteria* - J. E. McKee and M. W. Wolf, California State Water Quality Control Board, Sacramento, California, 1963, 2nd edition.

6. *Water Quality Criteria* - National Technical Advisory Committee, Federal Water Pollution Control Administration, Washington, D. C., 1968.

F. Physical and Chemical Properties

1. *Solubilities of Inorganic and Organic Compounds* - H. Stephen and T. Stephen, Macmillan, New York, 1963, Vol. 1, Part 1.

2. *Selected Values of Heats of Combustion* - A. P. Kudchadker, G. H. Alani and B. J. Zwolinski, Chemical Reviews, 68, 659 (1968).

3. *Physical Properties of Hydrocarbons* - R. W. Gallant, Gulf Publishing Co., Houston, Texas, 1968, Vol. 1; 1970, Vol. 2.

4. *International Critical Tables* - McGraw-Hill, New York, 1926.

5. *Handbook of Chemistry and Physics* - R. C. Weast (edit.), CRC Publishing Co., Cleveland, Ohio, 1972, 53rd edition.

6. *The Properties of Gases and Liquids* - R. D. Reid and T. K. Sherwood, McGraw-Hill, New York, 1966, 2nd edition.

7. *Thermal Conductivity of Gases and Liquids* - N. V. Tsederberg, MIT Press, Cambridge, Mass., 1965.

8. *Lange's Handbook of Chemistry* - N. A. Lange, McGraw-Hill, New York, 1969, 10th edition.

9. *The Chemical Thermodynamics of Organic Compounds* - D. R. Stull, et al., Wiley, New York, 1969.

10. *Matheson Gas Data Book* - Matheson Co., Inc., 1966, 4th edition.

11. Physical Properties of Chemical Compounds - R. R. Dreisbach, American Chemical Society, Washington, D. C., Vol. 1 (1955), Vol. 2 (1959); Vol. 3 (1961).

12. Beilsteins Handbuch der Organischen Chemie - Springer, Berlin, Germany.

13. Gmelins Handbuch der Anorganischen Chemie - Verlag Chemie, Weinheim, Germany.

14. Solubilities of Inorganic and Organic Compounds - A. Seidell and W. F. Linke, Van Nostrand, New York, 1941-1952, 3rd edition and supplement.

15. Selected Values of Physical and Thermodynamic Properties of Hydro-carbons and Related Compounds - F. D. Rossini, et al., American Petroleum Institute Project 44, American Petroleum Institute, Pittsburgh, Pa., 1953.

APPENDIX B-V

Methods Employed in Estimating Fire Hazard Data

Flammability Flash Point

Burgoyne and Williams-Leir[1] developed an equation for estimating closed flash-points, T_f, of single liquids from standard flammability data; values calculated in this manner were generally slightly lower than those determined by the standard laboratory methods. The equation is

$$T_f = \frac{A}{2 + B - \log_{10} y} \qquad (1)$$

where y = lower limit of flammability (% vapor) and A, B are the constants in the vapor pressure equation

$$\log_{10} P = \frac{-A}{T} + B$$

Burgess[2] has suggested that a hydrocarbon will flash at a temperature approximating to that at which its vapor pressure, P_F, is 12 mm mercury, whilst Bass et al.[3] assume a P_F value of about 8 mm mercury. Mullins[4] derived for petroleum products a better generalization for flash-points, viz.:

$$P_F\bar{M}' = 800 \pm 30 \qquad (2)$$

where $\bar{M}'$ is the mean molecular weight of a vapor bubble. The ± 30 tolerance corresponds to less than $\pm$ 1/2 C° on estimated flash-point. If $\bar{M}'$ is not known, but only $\bar{M}$, a less exact rule might be used in the following form:

$$P_F\bar{M} = 1100 \pm 100 \qquad (3)$$

where $\bar{M}$ is the mean molecular weight of the fuel.

Another relation connecting flash-point and volatility was derived by Butler et al.[5] for a large number of pure hydrocarbons and closely fractionated narrow-boiling cuts, namely,

$$T_F = 0{\cdot}683T_B - 119 \qquad (4)$$

where T_F = flash-point (closed-cup), °F and T_B = hydrocarbon boiling point, °F.

Equation (1) can be used to either determine the flash point from the lower flammability limit or to determine the lower limit of flammability from the flash point. Equations (2), (3), and (4) can be used to determine or confirm the flash points.

Ignition Temperature

Ignition temperature is greatly dependent on a number of experimental variables (volume of flask used, wall materials, etc.) so that it is not possible to relate ignition temperature to physical and chemical properties of the material. For pure hydrocarbons, reference[6] gives a plot of the minimum ignition temperature versus average carbon chain length. This is shown in Figure B-V-1.

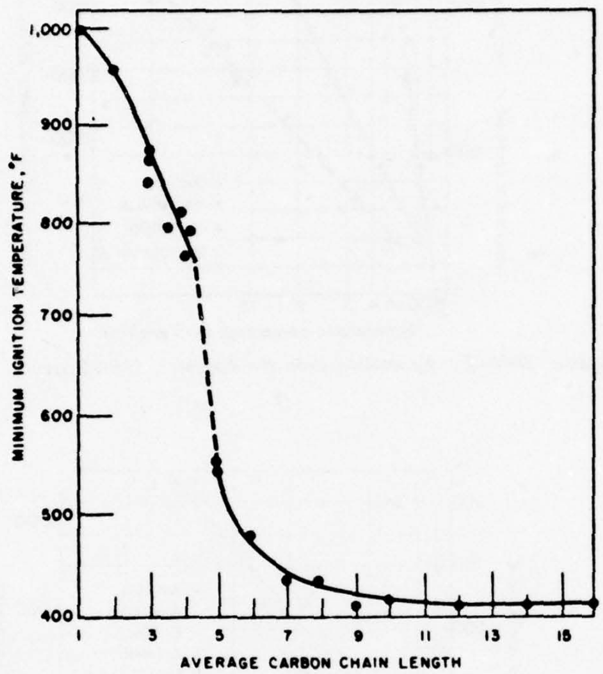


Figure B-V-1. *Minimum ignition temperatures of hydrocarbons of various carbon chain lengths.*

Flammability Limits

Lloyd [7] plotted flammability limits for various hydrocarbon series vs. the net heat of combustion in K cal/g mole. This graph is shown in Figure B-V-2 and it is seen that for weak limits there is a linear relation.

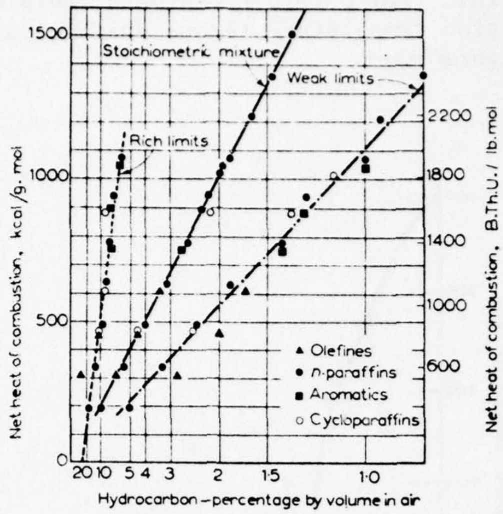


Figure B-V-2. *Flammability limits of hydrocarbons. (After* LLOYD[7])

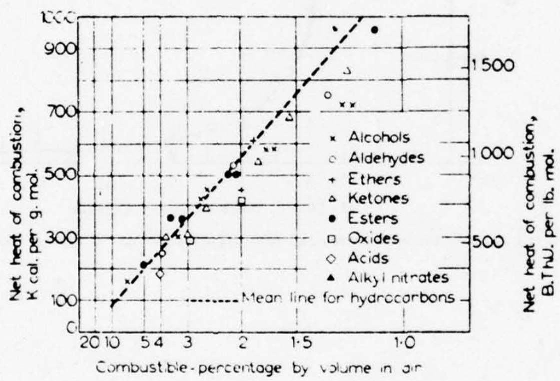


Figure B-V-3. *Weak limit of flammability for various organic substances. (After* LLOYD[7])

The rich limit is more complex as excess fuel, which is the diluent, will suffer pyrolysis giving various products with absorption or liberation of heat.

The calorific value of lower limit mixtures has often been found to be approximately constant. An average weak limit calorific value of

10.40 Kcal/mole was found. This value, together with the net calorific value per mole of the fuel enabled the weak limit to be derived from the equation:

$$\text{Weak limit} = K(\text{Net cal. value})^{-1}$$

where K = constant. Spakowski[8] then calculated rich limits using the equation:

$$\text{Rich limit} = 7{\cdot}1\ (\text{Weak limit})^{0{\cdot}56}$$

He also was able to estimate flammability ranges from the equation:

$$\text{Flammability range} = 143\ M^{-0{\cdot}70}$$

where M = molecular weight of the fuel.

Weak and rich flammability limits can also be calculated using the true partial pressure equation and Lloyd's rules for hydrocarbons, viz.

$$\text{weak limit} = 0{\cdot}55 \times \text{stoichiometric mixture}$$

$$\text{rich limit} \simeq 3{\cdot}30 \times \text{stoichiometric mixture}$$

If the closed cup flash point of a liquid is known and also the vapor pressure at the flash point temperature, the lower flammable limit for the vapor (at the flash point temperature) in percent by volume at normal atmospheric pressure may be calculated as follows:

$$LFL = \frac{P_f}{0.147}$$

where LFL is percent vapor by volume at lower flammable limit, and P_f vapor pressure, psia, at flash point temperature.

Burning Rate

To find the burning rate of burning pools of flammable liquids, a correlation found by Burgess,[2] et al. is used.

$$R \simeq 1.267 \times 10^{-4} \frac{\Delta H_C}{\Delta H_V} [1 - e^{-KD}]$$

where R = linear burning rate (cm/sec)
ΔH_C = net heat of combustion (cal/gm)
ΔH_V = sensible heat of vaporization (cal/gm)
D = diameter of spill (cm)
K = attenuation or extinction coefficient (cm^{-1})
for large fires (i. e. D >> 10 ft), $e^{-KD} \simeq 0$

Fire Extinguishing Agents Recommended

Evaluation of this item will be made by considering various physical and chemical properties of the combustible material and a knowledge of the capabilities of existing extinguishing agents. Among the physical and chemical properties which are important are the physical state of the chemical, its specific gravity, and flash point. Extinguishing agents to be considered are: water, dry chemicals, foams (aqueous film forming foams, protein foams, fluoro-protein foams), halon 1301, halon 1211, CO_2 and other special agents for self heating chemicals. The capabilities of these agents are well-known and described in NFPA's Fire Protection Handbook[6].

Fire Extinguishing Agents Not Recommended

The reactive properties of the chemical will be evaluated with respect to the capabilities of and possible interactions with the various extinguishing agents.

Special Hazards of Products of Combustion

We will examine the chemical composition of the combustible material and predict likely products of combustion. For example, halogen-containing compounds will produce hydrogen halides and their corresponding phosgenes; sulfur-containing chemicals will produce sulfur dioxide and so on. High molecular weight hydrocarbons and organic chemicals will produce smoky flames containing eye- and throat-irritating products.

Behavior in Fires

We will use judgment based on a knowledge of the physical and chemical properties of the spilled chemical and/or previous experience with the chemical. The behavior of combustible materials is predictable. Non-combustibles (e.g., H_2SO_4) will dissociate or evaporate producing predictable products the properties of which can be evaluated.

Electrical Hazard

This item is derived from UL experimental data which have been compiled by NFPA in its Electrical Code (volume 5)[9]. It covers very specific combustible gases and liquids. This table will be used to check the data reported in Manual 2.

Appendix B-V References

1. J. H. Burgoyne and G. Williams-Leir, "Limits of inflammability of gases in the presence of diluents - a critical review", Fuel, 27, 118 (1948).

2. S. G. Burgess, "The chemical aspects of petroleum acts", J. Inst. Petrol. 33, 363 (1947).

3. E. L. Bass et al., "The gas turbine and its fuels", Shell Aviation News No. 156, p. 16 June (1951).

4. B. P. Mullins, "Bubble-points, flammability limits and flash points of petroleum products" Combustion Researches and Reviews (1957) AGARDograph 15, pp. 55-75, Butterworths (1957).

5. R. M. Butler et al., "Prediction of flash-points of middle distillates", Ind. & Eng. Chem, 48, 808 (1956).

6. G. Tryon, editor, "Fire Protection Handbook" 13th edition, National Fire Protection Association, Boston (1969).

7. P. Lloyd, "The fuel problem in gas turbines", Proc. Inst. Mech. Eng., 159, 220 (1948).

8. A. E. Spakowski, "Pressure limit of flame propagation of pure hydrocarbon-air mixtures at reduced pressures", N. A. C. A. Research Memorandum E52H15 (1952).

9. NFPA "National Fire Codes--Electrical" volume 5, National Fire Protection Association, Boston (1972).

APPENDIX C

Assessment Models in Support of the Hazards Assessment Handbook

APPENDIX C

Assessment Models in Support of the Hazards Assessment Handbook

Scope, Content, and Status

The development of the Hazard Assessment Handbook required the use of a new existing assessment model as well as the derivation of several new analytical models to predict certain spill behavior. All the analytical models (existing or newly developed) actually used in the Hazard Assessment Handbook have been documented in a separate report.* This report, considered a part of CHRIS documentation, is not intended for field use. This report contains details of the analytical models (and their derivations) used in the CHRIS manual 3 for assessing the hazards caused by the spill of chemicals on water. The report is presented in two parts. Part I contains those models that have been based on the existing information in the literature, while Part II contains detailed derivations for each of the models that were developed. In general, Part II contains more sophisticated information. This report also includes discussions of the applicability of each of the analytical models to the different branches of the hazard assessment events chart.

Each model is given in a separate chapter and each chapter contains the following sections:

- Aim
- Introduction
- Assumptions and Principles
- Data Required
- Details of the Model
- Computational Algorithm
- Specific Example
- Discussions
- Conclusions
- References
- List of Symbols
- Appendix

---
*"Assessment Models in Support of the Hazard Assessment Handbook" Raj, P.H. and Kalelkar, A.S., NTIS #AD776617, United States Coast Guard Report #CG-D-65-74, January 1974.

The models are explained by first giving the principle on which the derivations are based and the major physical assumptions used. A specific example of each model is then presented to highlight the calculation procedure and to indicate the order of magnitude of the numerical values obtained. All the calculations are carried out in SI units and main results are indicated in tables and graphs. The list of symbols includes the definitions and values (or formulas) of the common symbols used in the text. In many cases the symbols are defined in the text also and their effects on the answers, as well as the extent to which the results could be used with confidence to describe the real system in nature are discussed. In general, the assumptions made are such that a conservative estimate of the hazard follows from using the model.

The hazard assessment model development program was initiated in the fall of 1972 and completed in December 1973. In the spring of 1974 the U. S. Coast Guard requested that seven new models be developed to represent additional spill situations not covered by the initial development of CHRIS. The new models development program was initiated in the summer of 1974 and completed in October 1975. The new models will not be incorporated into the Hazard Assessment Handbook pending field experience with the existing version of the handbook. The new models are, however, being incorporated in the Hazard Assessment Computer System (HACS) for use at USCG Headquarters.

A description of the hazard assessment models is included as an Adendum to this Appendix.

Relationship of Models with Content of Hazard Assessment Handbook and HACS

As indicated in Section 4.3.2, the actual assessment models were deemed too complicated for direct field use. It became necessary to reduce the models to a series of graphs and tables to satisfy field use requirements. In order to keep the number of such graphs and tables manageable and an assessment procedure sufficiently generalized to treat hundreds of hazardous chemicals, certain approximations were made in the models which led to a simpler output more suited to field needs.

As a result, there is not a one to one correspondence between the output of the Hazard Assessment Handbook and a direct exercise of the corresponding model as presented in this report. However, the differences in output are small and the results obtained by either method are quite usable in any accident situation.

There is a greater correspondence between the models as presented in this report and utilized in HACS. The primary difference arises from the fact that in computerizing the models for HACS use certain numerical schemes were utilized which adds a slight uncertainty in the output. However, a comparison of the output of each model (exercised manually) and the corresponding model in HACS indicated very slight differences in value and either value would be considered quite acceptable for hazard assessment.

New Models Currently Under Development

In reviewing the capabilities of the Hazard Assessment Handbook and HACS, both ADL and the U.S. Coast Guard agreed that whereas the handbook contained methods to assess the hazard due to several hazardous chemical spill situations and was adequate for introduction to the field offices, HACS should be further expanded to include several additional assessment models to make HACS even more valuable in treating common hazardous situations not covered by our original scope of work.

In the original development of the Hazard Assessment Handbook and HACS, a hazard assessment tree was developed which identified, in concept, most interactions that could occur when a hazardous chemical is released. This hazard assessment tree, however, did not identify in detail all of the conceivable processes that could influence the hazardous effects produced by the release of specific chemicals. In its present version, the assessment tree does identify and, in fact, directs the user to the analytical models that presently exist and that are deemed to be most important in responding to emergencies.

In reviewing the first version of the Hazard Assessment Handbook and HACS, it was felt that additional important spill situations which were not a part of the original development of HACS should be modeled analytically and incorporated into HACS.

The six new hazard assessment models currently being developed were chosen (after preliminary discussion with the U.S. Coast Guard) because they represent fairly common hazardous spill situations which were not presently covered in HACS. Each situation is discussed below:

1. Release and migration of heavy insolubles on river beds

(e.g., methyl bromide, chloroform)

There are some 30 chemicals in the original list of 400 which are liquids, heavier than water and either insoluble or partly soluble in water. For these chemicals, we can calculate the time to sink to the waterway bottom and the magnitude of the lateral movement due to currents during sinking. However, once the chemical has reached the river bed, it will spread and migrate downstream. Such migration can result in potentially hazardous situations, particularly if the chemical works its way into shallow water and starts evaporating due to reduced static pressure. The migration of heavy insolubles represents an important spill situation, and an assessment model for it needs to be developed.

2. Heating, rupture, and release of pressurized cargo in a fire

(e.g., an oil-carrying barge collides with a pressurized propylene carrier and the oil barge catches on fire)

The heating, rupture, and release of a pressurized cargo may result when a barge carrying pressurized cargo is involved in a fire due to any potential occurrence (such as collision with an oil carrier). Under such circumstances, it is important to determine the expected time to rupture, type of cargo release (explosive, turbulent jet, etc.) and fragmentation damage possibilities. Over 35 of the original 400 chemicals could be involved in a spill situation of this type.

3. The release of three specific reactive chemicals

In the initial version of HACS, reactive chemicals (self reactive, water reactive, or air reactive) were not modeled from a hazard assessment point of view due to complexities in modeling and lack of reaction rate data availability in CG-446-2, Hazardous Chemical Data. About 40 chemicals of this type are not adequately treated in HACS. Chemical specific hazard assessment models for three reactive chemicals will be chosen so they represent between them a large variation in physical and chemical interaction with water and air. It is envisioned that once three widely different reactive cases have been modeled, many of the remaining chemicals may be modeled by analogy by USCG technical personnel.

4. Release, spread, dispersion, and fire hazard due to a continuous release of cold, liquefied gases

Although instantaneous release of liquefied flammable and toxic gases is rigorously treated in HACS, the case of slower, continuous release (as may occur when the tank rupture is limited to a small hole) has not been modeled. In general, treating a liquefied gas spill as instantaneous provides the largest hazard distances and therefore an assessment which is conservative from a safety point of view. However, for instantaneous spills the duration of hazard is small, and in any real spill situation involving a slow leak the duration would be quite long. The slow, continuous leak represents a realistic spill situation and needs to be modeled from a hazard assessment point of view.

5. Water dispersion of chemicals with finite solubility (i.e., neither instantly soluble nor totally insoluble -- e.g., chloroform)

The current method for determining water dispersion of a hazardous chemical utilizing HACS assumes the chemical to be either instantly soluble or else totally insoluble. Whereas many of the chemicals are either very soluble or almost insoluble in water, a modeling of the water dispersion problem utilizing finite solubility of the chemical would constitute a more realistic assessment model.

6. Heating and rupture of tanks on sunken barges carrying cryogenic materials

There is a growing trend toward shipping liquefied gases at low temperatures in insulated tanks rather than under pressure. Should a barge carrying a low-temperature liquefied gas sink, it would be vital to determine the time available for salvage or response prior to heating and possible rupture and sudden release of the cargo underwater. This spill situation represents a realistic potential accident which was not covered in our initial modeling effort.

The new models were completed in October 1975 and will be adequate for hazard assessment purposes in the use of CHRIS.

Recommendations for New Programs in Hazard Assessment

Methods of estimating the hazard due to the discharge of hazardous materials on waterways have been under development for some time and have recently been assembled for easy use in the Hazard Assessment Handbook (CG-446-3). This handbook presented a hazard assessment tree which identified, in concept, most interactions that could occur when a bulk hazardous chemical is released on water. In its present version, the tree not only identifies the interactions but directs the manual user to analytical models that presently exist and can be used for actual hazard assessment. Analytical models currently exist (or are under development under the additional models phase of CHRIS) for those spill situations which are considered most realistic and require emergency response.

However, some of the existing assessment models are purely analytical in nature and have not been verified by experiments. Experimental verification will add to the confidence with which they could be used. Suggested new programs in the experimental verification of select, existing assessment models are presented in program plan A.

In spite of the large number of assessment models either existing or under development for CHRIS, there are other potentially important spill situations for which no analytical models exist. Suggested new

programs in the development of new models to represent common spill situations are presented in program B.

Plan A - Experimental Verification of Existing Models

1. Experimental Study of a Flammable Cryogen Spill with Ignition (Hazard Assessment Code)

In the event that a flammable cryogen (such as LNG) is released on water and ignites upon release, a high intensity, short duration fire will result. The problem of simultaneous spreading of a chemical (on water) while it is burning has been solved analytically, but little experimental knowledge is available. A release of 10,000 tons of LNG could result in a burning pool of some 1/2 mile in diameter. Although such a fire would burn out in about five minutes, the flame height might be over one mile high. This kind of a fire could potentially cause severe damage over a large area.

An experimental program aimed at investigating spread rate, evaporation time, flame height, and radiation field about LNG pool fires would help verify the existing analytical model. LNG would be used as the test chemical, but the results of the program would apply to many other chemicals as well. This experimental program would require 2-1/2 to 3 man-years of effort and could be completed in 10 months.

2. Evaporation/Dispersion of High Vapor Pressure Chemical

Several chemicals, such as benzene, are shipped in bulk and if discharged on water will spread on the surface and vaporize by virtue of their high vapor pressure. Analytical models to predict the rate of evaporation and subsequent dispersion of a high vapor pressure chemical when released on water have been developed. Existing models may be sufficiently refined but cannot be used with confidence unless verified by experiment. An experimental program utilizing two test chemicals should be conducted to verify the existing assessment model. Benzene is suggested as one of the test chemicals. It is anticipated that the experimental program envisioned can be completed within 10 months and would require 1-1/2 to 2 man-years of effort.

3. Vent Fires

Although analytical assessment models exist for predicting the hazards due to fires caused by the venting of gaseous cargo, they lack experimental verification. A scaled experimental program to measure flame size, configuration, and duration of vent fires can be completed in 12 months and would require 1-1/2 to 2 man-years of effort.

Plan B - New Model Development

1. Release of Heavy Chemicals

The large release of heavy (soluble and insoluble) chemicals on water can be particularly dangerous since the chemical disappears from view. It can later accumulate at some point in the waterway or even work its way into shallow waters or water inlets and cause irreparable damage. An understanding of the hazards created by the release of such chemicals needs to be developed. In particular, a combined experimental and theoretical program is needed to experimentally study the movement of soluble and insoluble chemicals in flowing water and to develop sound analytical models to predict the migration of the chemical and assess the hazards presented to people, property, and the environment. This major program, utilizing at least two slightly soluble and two insoluble heavy chemicals, could be completed in 12 months and would require about 2 to 3-1/2 man-year level of effort.

2. Cargoes in Submerged Containers

There have been several known occurrences of barge sinkings. The behavior of pressurized or cold cargoes in specialized containers submerged in water is not well understood. Questions such as the following remain unanswered: Can the container explode? Is the designed venting capacity adequate? How long should one try to locate the cargo prior to giving up and clearing the area due to imminent rupture and explosion. An analytical program aimed at the evaluation of the hazards presented by sunken cold and/or pressurized cargo is needed and could be completed in six months with a one man-year level of effort.

3. Dispersion of Chemicals in Specific Waterways

It is not possible to develop accurate generalized models of dispersion of chemicals in water. The phenomenon of water dispersion is sensitive to actual waterway conditions and varies widely with different waterways. It would be to the U.S. Coast Guard's advantage to study dispersion in certain specific waterways which are heavily trafficked and where the frequency of hazardous chemical release is great. A specific evaluation of water dispersion hazards will result in far more accurate predictions of water dispersion, and corrective response measures can be implemented with dispatch. A program of identifying six important waterway segments and evaluating water dispersion therein could be accomplished in 12 months and would require about 2 man-years of effort.

It is recommended that the six projects outlined (3 in Plan A and 3 in Plan B) above be carried out. Upon completion of these projects the state of hazard assessment methodology will be a sufficiently advanced level as to permit adequate response to hazardous chemical spills by the U.S. Coast Guard for several years.

APPENDIX C - Assessment Models in Support of the Hazard Assessment Handbook

Addendum (a) - Description of Hazard Assessment Models

The model development program was aimed at satisfying hazard assessment requirements as identified in the Hazard Assessment Tree discussed in Section 4.3 of the main text. There are 12 basic models identified in the tree and these are:

Name of Model	Letter Code in Hazard Assess. Tree
Venting Rate	A
Spreading of High Viscosity Liquid	T
Mixing and Dilution	K,P
Vapor Dispersion	C,G,J,N,S,W
Flame Size	B,E,H,L,Q,U,Y
Thermal Radiation	B,E,H,L,Q,U,Y
Spread of Low Viscosity Liquid	T
Spread with Evaporation	D,F
Spread of High Vapor Pressure Chemical	V,W
Mixing and Dilution of High Vapor Pressure Chemical	R,S
Heavy, Cold Liquids	I,J
Radiation View Factors	B,E,H,L,Q,U,Y

In this section, an account is given of the aim of the model, the assumptions and principles involved in its derivation, the adequacy and reliability of the model, and need for additional work - if any.

Venting Rate Model (LNG, Crude Oil)

The aim of this model is to provide information regarding the rate of release of a chemical subsequent to an accident. Specifically, the time history of the tank conditions and the venting rates of gas and/or liquid subsequent to a rupture in the tank wall are to be provided by this model.

Basic thermodynamic principles are used in the derivations. It is assumed that the gases behave as ideal gases and that equilibrium thermodynamic relationships are applicable. While this is true in most cases (i.e., liquid venting and slow gas venting) there are cases in which the

dynamics of venting become as important as the thermodynamics. The latter situations occur when a highly pressurized vessel containing a cryogen suddenly bursts open. Only two tank wall thermal conditions are considered; namely, adiabatic and isothermal. It is expected that the results for other wall conditions will lie somewhere between the results obtained for adiabatic and isothermal conditions.

This venting model is quite adequate for prediction of rate of chemical release in an accident. One way of improving the model would be to develop solutions for tank-wall conditions other than adiabatic or isothermal. However, in real accident situations, it would not be easy to determine wall boundary conditions with any accuracy and a more accurate assessment of efflux is not likely.

The current model will predict rates of release correctly to within a factor of two. The largest uncertainty in the analysis comes from the tank-wall not being either isothermal or adiabatic. Besides, the spread models, dispersion models, etc. are applicable to instantaneously released mass only. Hence, so long as the release times are short (as would be the case for rupture in a pressurized container) Model A results do not affect the assessment results.

<u>Spreading of a Liquid on Water (Hexane, Crude Oil, etc.)</u>

The aim of the model presented in this section is to obtain the extent of spread and mean thickness of film at any given time after the spill of a certain amount of liquid. This model applies to liquids that are lighter than water, immiscible, and which do not vaporize.

The principal assumption on which this model is based is that all of the liquid is spilled in a very short time ("instantaneously"). The properties of the spreading liquid and the total mass of the liquid in the "slick" are assumed to be constant during the spread. The derivations are based on the principle of balancing a spreading force and a resisting force.

This model has been partly verified by experimentation. Although no real spill is truly "instantaneous," most massive spills can be adequately represented by this model. For spills in large bodies of water, this model should be accurate to within $\pm$ 50%.

In real situations such as spills in harbors or open sea, the effects of the wind, waves, and water current are predominant. In the spreading model presented, these effects have not been considered and therefore will constitute a limitation. The assessment will therefore be sensitive to the above factors. The assumption of instantaneous spill may not be very serious if the time at which hazard is assessed is large compared to the total spill time.

For large volume spills, the radius of spread is proportional to 1/3 power of the volume for any given time (in the gravity-viscous regime). The radius is also sensitive to the difference between the densities of water and the spreading liquid when the liquid density is very close to that of water.

<u>Model T (Spreading of a High-Viscosity Liquid)</u>

- Radius of spread has different relationships with the physical parameters, depending on the regime of spread (gravity-inertia, gravity-viscous, and surface tension-viscous)
- For most real spill situations, the regimes of concern are the gravity-viscous and surface tension-viscous.
- In the gravity-viscous regime, the radius of spread is strongly dependent on the volume of liquid spilled, varying as the 1/4th power of the volume. However, the effect of change in density difference (between densities of water and liquid) is considerable when this difference is a very small fraction of the density of water. The radius varies as the 1/4th power of the effective gravity (i.e., density difference).
- In the surface tension regime, the radius of spread is a strong function of the surface tension of the liquid (1/2 power), but is not dependent on the volume of spill.

Mixing and Dilution (Methyl Alcohol)

The aim of this model is to present methods for calculating liquid concentrations in water after the spill of a water-miscible liquid.

The following assumptions were made in deriving this model:

- No heat transfer, chemical reaction, or phase change effects were considered; that is, the total mass of the liquid which is mixing with water remains a constant.
- No rapid settling of the liquid due to higher density effects was included.

This model consists of a series of sub-models to treat different types of waterways (e.g., tidals, non-tidal, etc.). Several generalizations were made in the development of this model, but the model is still considered adequate for the pure mixing and dilution problem. The results predicted by this model are expected to be accurate enough for post-spill planning.

The concentration predicted by the sub-models in the above model is sensitive to:

- Mean flow velocity: For non-tidal wide rivers, the maximum concentration value is not affected per se at any given downstream position by different stream velocities. However, the time at which maximum concentration occurs is a strong function of stream velocity.
- Mass of liquid spilled: The maximum concentration at any location downstream is a direct function of the spill quantity.
- River Geometry: If the river has a rough bed, or if it is narrow, the mixing is rapid and hence at any given downstream distance the peak concentration will be reduced.

- Tidal amplitude and period: For tidal rivers, the concentration is a strong function of these quantities. However, since the variability in tidal period for any location is not very large, the only parameter of interest is the tidal amplitude (in tidal velocity).

- Estarine regions: The stratification of salt (density) in estuaries has a very strong influence on the concentration of a chemical at any location at given time after the spill. Greater mixing is achieved with increased mean flow velocity and longer length of the estuary. However, the dependence of mixing process on the latter is quite weak.

Vapor Dispersion (Methyl Bromide)

The object of the derivations and equations in this model is to obtain the vapor concentration at any position in space and at any time after a hazardous vapor cloud is released into the atmosphere.

In using this model, the following assumptions have to be noted:

- The vapor that is diffusing is neutrally buoyant; that is, there is no gross movement of the vapor cloud caused by either gravity or buoyancy.

- Mixing with air is uniform throughout the cloud.

- The concentration obtained is time-averaged.

The methods developed to predict vapor dispersion are fairly standard and widely accepted by the Atomic Energy Commission and the Environmental Protection Agency. Except in unusually unsteady weather conditions, the average concentration predicted by this model will be accurate to within a factor of 2 or 3. This is considered adequate for hazard assessment.

The important parameters that affect the vapor concentration at large distances (compared to the initial size of the vapor cloud) are:

- Atmospheric stability: Has a strong influence on the concentration.

- **Wind velocity:** Has very weak influence on the concentration value for vapor released over a very short duration of time. However, for maintained (continuous) sources, the concentration at any place is inversely proportional to the wind velocity.

- **Mass of vapor:** Concentration is directly proportional to vapor mass released.

- **Vapor buoyancy:** Even though this is not considered explicitly in the model, it can be said that the greater the vapor buoyancy, the lower is the ground level concentration (for a ground level source) at any point downwind of the source. The height of the effective source is roughly proportional to the square root of the initial buoyancy flux and inversely proportional to the wind velocity.

  In effect, the rate of release of a buoyant vapor rising vertically strongly influences the downwind ground level concentration for distances close to the source. However, for large downwind distances, this effect is relatively small.

Flame Size (LNG, Propylene, Gasoline, Aceytelene)

The object of the flame size models is to obtain the length, diameter, and inclination of flames during the burning of a gas or a liquid burning from a pool.

In the case of burning of a gas jet, it is assumed that the flow in the jet is turbulent and that the plume is like a cone with constant angle opening. It is also assumed that the buoyancy does not affect the flame in any way (since the velocity of jet is quite high, this is generally true), and also wind blowing has little effect on bending the flame.

The model for gas jet is conservative. The model for flame height from liquid pool fires is adequate for hazard assessment purposes.

The important parameters on which the flame length of a burning jet of gas issuing from a hole depends are:

- Fuel property: The primary fuel properties on which the length is dependent are the molecular weight and the air/fuel ratio. For an increase in molecular weight by a factor of about 20 (from 2 for hydrogen to 43.2 for propane), the flame length at the same nozzle velocity (200 fps) and nozzle diameter (1/8") increases by a factor of about 2.
- Diameter of the hole: The flame length is directly proportional to the hole diameter. However, the length is very weakly dependent on the gas velocity, provided the flow is turbulent.

The hazard distances for such shooting flames depends not only on the flame length and radiative temperature, but also on the orientation of the flame axis relative to an observer.

For pool burning flames, the parameters that affect the flame size (and therefore the hazard distances) are:

- Burning rate: This is not a controllable parameter because the rate of liquid evaporation depends on the heat radiation from the flame and other sources. However, the size (length) of the flame increases roughly as the square root of the burning rate per unit area of the pool.
- Diameter of pool: The flame length increases roughly as the 3/4 power of the diameter; i.e., for a 10-fold increase in diameter, the flame length increases by a factor of about 5.5.
- Hazard distance: If the hazard considered is such that the radiation level at the hazard distance is in the inverse square law region (e.g., skin burn), then the hazard distance increases as the 0.85 power of the pool diameter, i.e., for a 10-fold increase in diameter the distance (from the pool center) increases by a factor of about 7.

<u>Thermal Radiation</u>

The aim of this section is to provide formulas and correlations to predict the radiant heat transfer from the flames of different fuels.

The main assumption made in calculating the radiant heat transfer from the flame to a body outside it is to treat the flame as a cylindrical object of uniform temperature. This cylindrical plume may be inclined to the vertical.

This model is based on sound physical principles and has been verified by experiments. It is quite adequate for use in CHRIS.

The main parameters of interest in this model are:

- Flame temperature: Even though this is an average blackbody temperature of the flame, the radiation level at any distance is strongly dependent on this temperature. A mere 10% change in this temperature produces a 40% change in the radiation level.

  It is possible, however, because of the distribution of temperature within the flame (hot near the bottom and colder at the top) that as one approaches the flame bottom the radiation received may be higher than that predicted by a single mean flame temperature. The error in this case depends on the size of the flame, nature of fuel, and other environmental conditions that affect the temperature distribution within the flame.

- Emissivity: The flame *emissivity* depends, to a large extent, on the density and size of soot particles, the local temperature within the flame, and the size of the flame. It is an extremely complicated function of these parameters. It is hard to describe its variation in precise quantitative terms, but generally, emissivity increases with an increase in the diameter of the flame. For sooty flames, 5-to 10-ft diameter flames will effectively behave as blackbodies ($\varepsilon = 1$)

Spreading of Low-Viscosity Liquid

The aim of the derivations for this model is to obtain expressions for the extent of spread at any time after a sudden spill of a low-viscosity liquid on a high-viscosity liquid, e.g.:

In deriving the equations for the spread, the following have been assumed:

- The total mass of the spilled liquid remains the same during the spread; that is, there are no evaporative or dissolution effects, nor does the liquid react with water.
- The physical properties of the liquid and water do not change.
- The liquid is lighter than water, has very low viscosity, and is immiscible with water.
- The spill occurs instantaneously.

This model is based on sound physical principles and can be used with confidence in assessing the hazard due to massive releases of low-viscosity liquids on water.

The important parameters on which the radius of spread at any given instant depends are:

- Volume of spill: In the gravity-viscous regime, the radius depends on the 3/8 power of volume; i.e., for a 10-fold increase in spill volume, the radius (at a given time) increases by a factor of about 2.5.
- Effective gravity: The radius is a very weak function of the effective gravity (i.e., on the difference in liquid-water density). For a 10-fold increase in effective gravity, the radius increases only by 1.3 times.
- Viscosity: In both the gravity-viscous and surface tension-viscous regime, the radius is inversely proportional to a fractional power of the viscosity of liquid. Both functions are relatively weak. However, unlike the case of a high-viscosity liquid spread on water, the radius of spread does depend on the liquid viscosity, provided it is much smaller than that of water (by about a factor of 10).
- Surface tension: The spread radius increases as the 1/4 power of the surface tension. This is therefore a relatively weak function. A 10-fold increase in surface tension causes only a 1.8 times increase in radius.

Spreading and Evaporation of Cryogens on Water (LNG, Propylene)

The aim of this model is to obtain the spread rate, the time for complete evaporation, and the maximum extent of spread of a cryogenic liquid spilled on a water surface.

The assumptions made in the derivation of the model follow:

- The liquid is lighter than water and immiscible with it.
- The heat for evaporation of liquid comes primarily from water.
- The spread area is a continuous mass of liquid at every instant.
- The spill occurs instantaneously.
- The properties of the liquids do not change during the spread.

Because of the violence associated with the boiling of a cryogenic liquid on water, the third assumption - the continuous slick - may not always be true in reality.

This model requires rates of heat transfer between water and the released cryogen. Whereas some heat-transfer data are available (e.g., LNG), for many cases educated guesses have to be made. It should be noted, however, that the actual time for total evaporation and maximum pool radius is not overly sensitive to the heat-transfer rate. The model is adequate for CHRIS. Additional heat-transfer data would be useful.

In this model, with the cryogen boiling on water with a uniform heat flux from water, the parameters of interest are the maximum radius of spread and the duration of spread. These depend on:

- Volume of spill: Both the total time for evaporation and maximum radius are relatively weak functions of the volume of spill. For example, for a 10-fold increase in spill volume, the evaporation time increases only by 1.8 and the radius by 2.4.
- Liquid regression rate: The time for evaporation is more sensitive than radius to the regression rate. For a 10-fold increase in regression rate, the evaporation time decreases by a factor of 3 whereas the maximum radius decreases only by a factor of 1.8.

- Effective gravity: Both time and maximum radius are weak functions of this parameter. However, the effect is different for the two. The evaporation time decreases by a factor of about 2, and radius increases by a factor of about 1.3 when effective gravity increases by a factor of 10.

Spreading and Cooling of a High-Vapor Pressure Chemical

The aim of this model is to obtain the extent of spread and the vaporization rate at any instant of time after the instantaneous spill of a high-vapor pressure, lighter-than-water liquid on water.

The basic principle of the model is the vapor-pressure-difference-driven evaporation and the consequent cooling of the liquid. The liquid also spreads simultaneously. There is also heat addition to the liquid from water because of the thermal gradient in water. The other assumptions made in the derivation include:

- All of the liquid is spilled instantaneously.
- The spreading is independent of evaporation.
- Entire liquid mass is at a single temperature (mixed mean temperature) at every instant of time; that is, there are no thermal gradients in the liquid mass itself.
- Liquid and water properties are constant.
- The mass-transfer coefficient is constant.
- Evaporation is caused by a vapor concentration difference between the vapor just above the liquid surface and the vapor in the atmosphere. Also, it is assumed that the vapor concentration in the atmosphere is zero.
- The temperature of the spilled liquid is the same as that of the water temperature.

The assumption of uniform liquid temperature is very idealistic. In fact, there will always be longitudinal and even thickness-wise thermal gradients in the liquid. However, in the interest of simplifying the problem, this assumption is made. Also, it is noted that the temperature so obtained gives a "mean" temperature. The assumption

regarding the initial liquid temperature is questionable. If the liquid is hotter than water, it loses heat first to water and then starts cooling because of evaporation.

Although this model is based on sound physical considerations, many simplifying assumptions had to be made in the model derivation. Verification of model by experimentation would greatly increase the confidence with which the model could be used.

The parameter of interest in the model is the total time of evaporation of the chemical. This depends to a large extent on the thermodynamic properties of the chemical (vapor pressure), the ambient conditions, and the water temperature. The dependence of this evaporation time on these individual parameters is an extremely complicated function. Only certain very general statements can be made:

- Volume of spill: The evaporation time increases roughly as the 1/3 power of the volume if the rest of the conditions remain the same.
- Initial vapor pressure: The time to evaporate decreases in direct proportion to the magnitude of the vapor pressure at the water temperature.
- Effective gravity: The evaporation time decreases roughly as the 1/2 power of the effective gravity. This relationship is based on the assumption that the area of spread is proportional to the 1/2 power of effective gravity which occurs in the gravity-inertia regime of spread.
- Properties of water: Because of the assumption in the model that the heat transfer to the evaporating liquid is conduction-limited on the water side, the time to evaporate decreases almost inversely with the combined water property $\sqrt{k\rho c}$, where k = thermal conductivity, ρ = density, and c = specific heat of water.

Mixing and Dilution of a Soluble High-Vapor Pressure Chemical (Methyl Alcohol)

The objective of the model is to predict the vapor liberation rate as well as the area and the duration over which the vapor is liberated

when a highly water-soluble, high-vapor pressure liquid is spilled on a water surface.

The assumptions made in the development of this model include:

- Evaporation of the chemical takes place only at the water atmosphere interface and is a consequence of the difference in the concentration of the vapor (of the chemical) over the water surface and in the atmosphere.
- The chemical spilled reaches the temperature of the water instantly.
- The partial vapor pressure over water can be represented by $p = c_m p^{sat}_{vap(l)}(T)$ where c_m is the molar fractional concentration in water.
- To estimate the water dispersion (and hence surface concentration), we assume that the entire mass of the liquid spill goes into solution with water. It is, in effect, an "a priori" assumption for a very small mass of vapor liberation.
- Instantaneous spill at a point is assumed for calculating the water dispersion.

This model, too, requires experimental verification to increase its reliability.

The sensitivity of the results obtained in this model depend, to a large extent, on the following parameters:

- Stream velocity: Increased stream velocity promotes better mixing and results in lower concentrations of the chemical on the water surface. Consequently, the total mass of vapor liberated will be reduced. The total evaporation rate is directly proportional to the mean stream velocity.
- Vapor pressure: The vapor pressure of the chemical mixed with water determines the rate of vaporization. Since this vapor pressure depends not only on the property of the chemical (its saturation pressure at ambient temperature), but also on the dilution at the water surface, only qualitative statements can

be made. The mass rate of vaporization depends directly on the saturation vapor pressure. Also, the wind conditions in the atmosphere affect the vaporization rate. Typically, for a 100% change in wind velocity, there will be a 180% change in evaporation rate (assuming turbulent mass transfer relationships).

- Mass of chemical spilled: All other parameters being constant, the fraction of mass spilled that vaporizes increases as the 1/3 power of the mass spilled. However, this fraction is very small for highly miscible fluids.

Boiling Rate for Cold Heavy Liquids (Chlorine, Methyl Bromide)

The aim of the model presented below is to obtain the rate of evaporation and the total time for which a liquid will evaporate when it is spilled on water and sinks. The boiling point of the liquid is less than that of water.

The basic principle on which the derivation is based concerns the breakup of a large blob of heavy liquid into smaller drops and their subsequent evaporation due to heat transfer from the surrounding medium (in this case, water). The assumptions made in deriving the model are given below:

- The blob of liquid spilled breaks up into small drops instantaneously, and these drops attain their terminal velocities in a very short time with very little evaporation.
- All the drops formed are of the same size.
- The drop cluster formed has high porosity; that is, the inter-drop distances are large enough so that, as a first approximation, the effect of other drops on the motion of any single drop in the cluster can be neglected. In short, we assume that the motion of each drop is independent of all others.
- The critical Weber number is 8; that is, any drop moving at a velocity greater than that for which the Weber number is 8 breaks up.

- Forced convection heat and mass transfer results are assumed to apply.

There is some experimental verification for this model. Additional experimentation would provide valuable insights and strengthen the hazard assessment procedure. The model is adequate, however, for use in CHRIS.

The primary quantity of interest in this model is the duration of the time within which all of the liquid spilled evaporates due to heat transfer from water.

The parameters that determine the rate of vaporization of the liquid are:

- Initial drop radius: This quantity depends upon the interfacial tension, the effective gravity, and the density of the water in which the liquid is sinking. For a 100% change in the value of the interfacial tension, a corresponding change of 50% in the initial drop radius results.
- Boiling temperature: The evaporation rate is directly proportional to the temperature difference between the water and the liquid.

The evaporation rate is roughly proportional to the -0.8 power of radius. The time for evaporation therefore increases as the 1.8 power of radius, i.e., 0.9 power of surface tension; i.e., for an increase of surface tension by a factor of 10, the time for complete evaporation increases by about a factor of 8.

Radiation View Factor

Since the radiation view factor is a geometric quantity, it is dependent purely on the geometric size of the cylindrical flame and the relative distance and orientation of the radiation-receiving element. Because of the complex nature of the formulas, no sensitivity analysis can be made in a simple fashion. It can, however, be stated that for large distances of the receiving element ($x > 4D$), the view factor approaches the inverse square law $F \sim 1/x^2$.

APPENDIX D

Revised Specifications

APPENDIX D-I

Specifications for CG-446-1

Condensed Guide to Chemical Hazards (CHRIS)

Content Specifications

Local Contacts

Spaces should be provided for users to write in local telephone numbers and contact names at USCG, EPA, COE, NRC, RRC, state agencies, and poison control centers. Users should be advised that contact with local police, fire, and medical aid can be made through the telephone operator. Users should be referred to the notification section.

Table of Contents

Cite the numbered sections in the order in which they appear. List sub-sections down to the third level of subdivision. See Figure D-I-1.

Notification

State current Coast Guard policy for notifying other interested and responsible agencies in the event of an emergency.

How to Use CG-446-1

Present a brief stepwise method for employing the manual when responding to an emergency involving the potential or actual release of a hazardous chemical. For each step (e.g., identify the chemical, assess the hazard) that should be taken, give a reference to the manual.

Clearly state that the absence of a material from the manual does not imply that the material is not hazardous, and recommend that other sources of information be consulted when an unlisted material is encountered.

Information Needs for CG-446-3

List information needed to do hazard assessments with CG-446-3, Hazard Assessment Handbook, and the Hazard Assessment Computer System (HACS). Where relevant, briefly list suggested sources of this information. Include a summary sheet on which blank spaces can be filled in as the information is gathered.

The information needs listed should correspond to those listed in CG-446-3, Hazard Assessment Handbook, Section 3 - Information Needs.

Figure D-I-1

A Condensed Guide to Chemical Hazards

CG-446-1

Table of Contents

1. Notification 1-1

2. How to Use CG-446-1 2-1

3. Information Needs for CG-446-3 3-1

4. Where to Find Other Information 4-1

4.1 CHRIS 4-1

4.2 Other Information Systems 4-1

4.2.1 Chemical Transportation Emergency Center (CHEMTREC) 4-1

4.2.2 National Fire Protection Association (NFPA) 4-1

4.2.3 International Maritime Consultative Organization (IMCO) 4-2

4.2.4 Department of Transportation (DOT) 4-2

4.2.5 National Academy of Sciences (NAS) 4-2

4.2.6 OHM-TADS (EPA) 4-4

4.2.7 Poison Control Centers 4-4

5. Explanation of Data Sheets 5-1

5.1 General Format 5-1

5.2 Colors and Symbols 5-1

5.3 Content 5-1

5.3.1 Chemical Identification Data 5-1

5.3.2 General Response Information 5-3

5.3.3 Fire 5-5

5.3.4 Exposure 5-6

5.3.5 Water Pollution 5-8

6. Data Sheets 6-1

7. Compatibility Guide 7-1

8. Thesaurus of Synonyms 8-1

9. Code Listing 9-1

Where to Find Other Information

Explain what types of information are available in the other components of CHRIS.

Explain the use of other hazardous material information systems that might be encountered or could be helpful. Systems described should include CHEMTREC, NFPA 704M, IMCO, HI System, NAS Hazard Rating System, OHM-TADS, and poison control centers.

Explanation of Data Sheets

Describe the general format of the data sheets and the use of colors and symbols. Include a data sheet appropriately annotated for illustrative purposes.

Elaborate on the meaning of specific chemical characteristics and precautions wherever additional clarity may aid in the use of the manual. For example, the source of the chemical name, use of synonyms, and purpose of the code should be explained. Differences between such terms as combustible, flammable, and not flammable should be explained. For an explanation of the Data Sheet content, see Addemdum (b) (page D-22).

Chemical Data Sheets

Chemical Identification

Chemical Name

Cite the chemical name as given in the Code of Federal Regulations or, when the chemical is not listed in the CFR, cite the most common chemical name.

Code

Cite a three-character alphabetical designation for the specific chemical. (See Appendix B-III, Final Report, Development of Chemical Hazards Response Information System [CHRIS], October 1975.)

Common Synonyms

List several synonyms or commercial names that are most commonly used. If there are no common synonyms, leave space for future additions.

Appearance

See Figure D-I-2, Annotated Data Sheet.

Chemical Name	Code
Name that appears in the Code of Federal Regulations, or the common chemical name.	

Common Synonyms	Appearance		
Other names frequently used.	*Physical State as shipped*	*Color*	*Odor*
	Action on release into water.		

3 letter code for use in communications.

General Response Information (red)

Basic preventative and precautionary actions to be taken.

Fire *Titles are printed in red with bars to indicate the principal hazard(s).*	Hazards (black) *Information on flammability, toxic products of combustion, explosion hazard, etc.* Responses (red) *Extinguishing agents that should and should not be used, protective clothing required, etc.*
Skull-and-cross-bones appears if the material is poisonous. **Exposure**	Hazards (black) *Describes the hazards of exposure to the chemical in each of its physical states.* Responses (red) *First aid that should be administered to victims while awaiting medical assistance.*
Water Pollution	Hazards (black) *Indicates threat to aquatic life, shoreline, and water intakes.* Responses (red) *Tells who to notify*

CG 446--1

Figure 5.1 Explanation of Data Sheet

Physical State

Describe the physical state of the material as shipped, for example, watery liquid or solid crystals.

Color

Cite the color of the material as shipped using an adjective (light, dark) where appropriate. Materials that are colorless should be described as such. A range of colors may be given if the chemical is dyed by manufacturers or if the chemical changes color when exposed to air or moisture.

Odor

Cite the characteristic odor, or if odorless, so state. Use commonly understood terminology such as domestic type odor descriptions (e.g., garlic, ammonia).

Physical Action on Release

Describe the interaction between the chemical and water or air using standardized descriptive phrases such as those shown in Addendum (a) (page D-11). When the boiling point and/or the freezing point of the chemical is a temperature within the ambient range, cite this boiling (freezing) point in degrees Fahrenheit.

General Response Information

Cite the critical precautionary steps that should be taken in the event of a discharge (or potential discharge) of the material. Use standardized phrases such as those shown in Addendum (a). Include only those actions that might be expected of first-response personnel.

Hazard/Response Information

Fire

Cite the most critical fire hazards associated with the chemical and the most critical fire fighting procedures. Use standard phrases such as those shown in Addendum (a).

Exposure

Cite the most critical hazards produced by exposure to the chemical in each of the physical states in which it might be encountered, and list recommended first aid procedures. Use standard phrases such as those shown in Addendum (a). If the chemical is listed as a poison in the CFR or by IMCO, designate it as a poison.

Water Pollution

Cite the potential for water pollution and recommend notification of appropriate agencies. Use standard phrases such as those in Addendum (a).

Compatibility Guide

Reproduce the Guide to the Compatibility of Chemicals.

Index of Synonyms

Place all known English synonyms for all chemicals in a single listing arranged in alphabetical order. Cite the common chemical name that applies with each synonym.

Code Listing

List all three-character code designations in alphabetical order, and cite the chemical name that corresponds to each code.

Publication Specifications

Organization

CG-446-1 will be organized by titled major sections and sub-sections bearing arabic decimal classifications as follows:

1. Notification
2. How to Use CG-446-1
3. Information Needs for CG-446-3
4. Where to Find Other Information
5. Explanation of Data Sheets
6. Data Sheets
7. Compatibility Guide
8. Index of Synonyms
9. Index of Codes

Each major section will begin on a separate right-hand page. Each of the sections (except Section 6) will be individually paginated - Section 1 starting with 1-1, Section 2 starting with 2-1, etc. Section 6 will not be paginated. Each page of section 6 will be identified by the manual number (CG-446-1) in the lower right-hand corner.

Format and Layout

Method of Preparing Camera-Ready Copy

Sections 1 through 5 and 7 through 9 will be prepared on a cold-type composer. Section 6 will be prepared on a special mask with typeset chemical names and codes and composer test.

Overall Physical Appearance

A) Page Size: 8-1/2 in x 11 in.

B) Number of Pages: Approximately 470 for Edition 1 (400 chemicals), with one additional page for each new chemical added.

C) Type Size: 11-point Press Roman Bold for text; 10-point Press Roman Bold for synonyms; 36-point Tempo Bold Condensed for chemical names.

D) Colors: White stock.

E) Printing: Two-sided print. Black ink for text, red and black ink for Section 6, other colors as indicated on special pages.

F) Number of Chemicals: 400 initially; increasing in later editions.

G) Binding: Perfect bind.

H) Covers: Weather resistant. Front cover printed on both sides.

I) Number of Volumes: One.

Sections 1 - 5

These sections will be standard single-spaced typed text printed on white stock. Section 4 will contain several multicolor graphic pages.

Section 6

Section 6 will contain one page per chemical. Each page will be printed in red and black with the mask, chemical name, and approximately one-half of the text (hazards) in black and the remaining text (responses) in red.

Pages will be unnumbered and will appear in alphabetical order based on the full chemical name.

Each page shall be prepared on a mask as shown in Figure D-I-3. Within this framework, the chemical name and code will be typeset and all other information will be filled in using a composer.

Figure D-I-4 is a typical data sheet illustrating the methods of highlighting to be employed. Text will be highlighted where appropriate using capitalization. The principal hazard(s) of a material may be highlighted by printing a title in red and using parallel bars (as Exposure in Figure D-I-4). A skull-and-crossbones is used to denote poisonous materials.

On Figure D-I-4 also note:

- The arrangement of physical state, color, odor and action or release in the appearance box.
- The offsetting to the left of general response information to increase its visibility.

Figure D-I-3

Data Sheet	
Common Synonyms	

Fire	
Exposure	
Water Pollution	

CG 446-1

Figure D-I-4

# METHYL ALCOHOL	**MAL**

Common Synonyms	
Methanol **Wood alcohol** **Wood naphtha** **Wood spirit** **Pyroxylic spirit**	**Watery liquid** **Colorless** **Alcohol odor** **Floats and mixes with water. Flammable, irritating vapor is produced.**

Stop discharge if possible. Keep people away.
Shut off ignition sources and call fire department.
Stay upwind and use water spray to "knock down" vapor.
Avoid contact with liquid and vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire	**FLAMMABLE.** **Vapor may explode if ignited in an enclosed area.** **Flashback along vapor trail may occur.** Extinguish with dry chemical, alcohol foam, or carbon dioxide. Water may be ineffective on fire. Cool exposed containers with water.
 **Exposure**	CALL FOR MEDICAL AID. **VAPOR** **Irritating to eyes, nose and throat.** **If inhaled, will cause dizziness, headache, difficult breathing, or loss of consciousness.** Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen. **LIQUID** **POISONOUS IF SWALLOWED.** **Irritating to skin and eyes.** Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk and have victim induce vomiting. IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS, do nothing except keep victim warm.
Water Pollution	**Dangerous to aquatic life in high concentrations.** **May be dangerous if it enters water intakes.** Notify local health and wildlife officials. Notify operators of nearby water intakes.

APPENDIX D-I - Revised Specifications for CG-446-1

Condensed Guide to Chemical Hazards

Addendum (a) - Standard Phrases

Action on Release

For phrasing that designates whether the chemical floats, sinks, or mixes with water, see Figure D-I-5.

Reacts with water: Item 7.1 of CG-446-2 applies.

Reacts violently with water: Item 7.1 of CG-446-2 applies.

Floats and boils on water: Density less than 1.0 and boiling point is less than 30°F.

Sinks and boils in water: Density greater than one and boiling point is less than 30°F.

Flammable vapor produced: Applicable to flammable liquids, flammable liquefied gas and flammable liquefied compressed gases.

Flammable, irritating vapor is produced: Same as above with additional requirement that vapor be irritating as defined by designator (3) through (5) of item 5.8, Explanation of Terms, CG-446-2.

Poisonous vapor is produced: Used when chemical is poisonous as defined in CG-446-1, Explanation of Terms, and boiling point is less than 300°F.

Poisonous flammable vapor is produced: Used when chemical is poisonous (as in CG-446-1, Explanation of Terms) and the chemical is a flammable liquid, a flammable liquefied gas, or a flammable liquefied compressed gas.

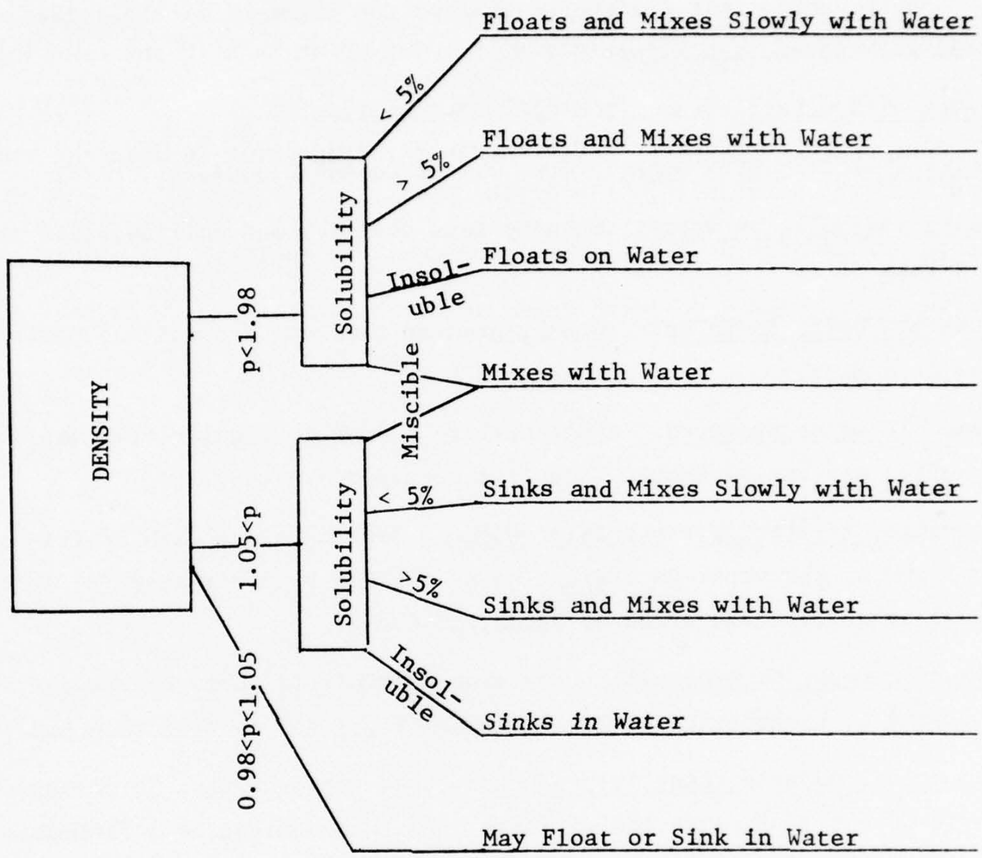
Flammable visible vapor cloud is produced: Applicable to flammable liquids, flammable liquefied gases, and flammable liquefied compressed gases that form visible vapor clouds. Chemicals whose boiling points are less than 0°F are assumed to cause visible vapor clouds.

Poisonous visible vapor cloud is produced: Same as the above, except that the vapor is poisonous but not flammable.

Poisonous, flammable, visible vapor cloud is produced: Used when conditions as defined for previous two phrases are appropriate.

Figure D-I-5

Standard Phrases



Visible vapor cloud is produced: See previous definition of visible vapor cloud. Not flammable; not poisonous.

Poisonous gas is produced on contact with water: Applies to chemicals that react with water and produce vapors that are deemed to be poisonous as defined in CG-446-1.

Boiling point is ______: Cited when boiling point is near the temperature of the surroundings (30 - 100°F.)

Freezing point is ________: Cited when freezing point is near the temperature of the surroundings (30 - 100 °F.)

Reacts slowly with water: Item 7.1 of CG-446-2 applies.

Ignites when exposed to air: Based on §7.2 CG-446-2.

General Response Information

Avoid contact with liquid: Applies when a liquid substance may cause irritation or more harmful effects.

Avoid contact with solid: Applies when a solid substance may cause irritation or more harmful effects.

Avoid contact with liquid and vapor: Applies when a volatile liquid can cause irritation or more harmful effects on exposure to either the liquid or vapor.

Avoid contact with liquid and solid: Applies when a substance, upon release, may be in either the liquid or solid form and irritation or more harmful effects may occur on exposure to the chemical.

Avoid contact with solid and dust: Applies to all solids that may be shipped in the form of granules, lumps or powders, that may cause irritation or harmful effects.

Wear goggles and self-contained breathing apparatus: See Explanation of Terms, CG-446-1.

Wear goggles, self-contained breathing apparatus and rubber overclothing (including gloves): See Explanation of Terms, CG-446-1.

Wear rubber overclothing (including gloves): See Explanation of Terms, CG-446-1.

Wear chemical protective suit: See Explanation of Terms, CG-446-1.

Wear protective suit with self-contained breathing apparatus: See Explanation of Terms, CG-446-1.

Shut off ignition sources: Applies to flammable and combustible liquids and vapors. See CG-446-1.

Stop discharge if possible: Applies to all chemicals.

Evacuate area in case of large discharge: Applies to all volatile chemicals whose vapor is toxic or flammable.

Call fire department: Applies to all flammable and combustible substances.

Stay upwind, use water spray to "knock down" vapor: Applies to all chemicals that produce flammable and/or irritating vapors.

Isolate and remove discharged material: Applies to all chemicals except those whose boiling points are less than 30°F.

Notify local health and pollution control agencies: Applies to all chemicals.

Keep people away: Applies to all chemicals except those which present no exposure or fire hazard.

Fire

Flammable: See Explanation of Terms, CG-446-1.

Combustible: See Explanation of Terms, CG-446-1.

Not flammable: See Explanation of Terms, CG-446-1.

May cause fire on contact with combustibles: Determined from Item 7.2, CG-446-2.

Poisonous gases may be produced in fire: Determined from Item 6.5, CG-446-2. Applies when it is uncertain whether or not a flammable chemical will produce poisonous gases when heated by the fire.

Poisonous gases are produced in fire: Determined from Item 6.5, CG-446-2. Applies when the products of combustion or decomposition are known to be poisonous.

Poisonous gases may be produced when heated: Determined from Item 6.5, CG-446-2. Applies when a material is not flammable nor combustible, but may produce poisonous gases when heated.

Poisonous gases are produced when heated: Determined from Item 6.5, CG-446-2. Applies when a material is not flammable nor combustible, but is known to produce poisonous gases when heated.

Irritating gases may be produced when heated: Determined from Item 6.5, CG-446-2. Applies when a material is not flammable nor combustible, but may produce irritating gases when heated.

Containers may explode in fire: See Explanation of Terms, CG-446-1. Generally not applied to volatile liquids that may overpressurize the container when heated.

Flashback along vapor trail may occur: Applies to all flammable liquids.

Flammable gases may be produced on contact with metals: Determined from Item 6.6, CG-446-2.

May explode if exposed to heat or flames: Applies to materials which decompose violently or explode in the presence of heat or fire.

Wear goggles and self-contained breathing apparatus: See Explanation of Terms, CG-446-1. Applies to protection against decomposition, reaction and combustion products as well as the chemical itself.

Wear goggles, self-contained breathing apparatus, and rubber overclothing (including gloves): See Explanation of Terms, CG-446-1. Applies to protection against decomposition, reaction, and combustion products as well as the chemical itself.

Wear rubber overclothing (including gloves): See Explanation of Terms, CG-446-1. Applies to decomposition, reaction and combustion products as well as the chemical itself.

Wear chemical protective suit: See Explanation of Terms, CG-446-1. Applies to decomposition, reaction and combustion products as well as the chemical itself.

Wear chemical protective suit with self-contained breathing apparatus: See Explanation of Terms, CG-446-1. Applies to decomposition, reaction and combustion products as well as the chemical itself.

Extinguish with water, dry chemicals, foam or carbon dioxide: Determined by Item 6.3, CG-446-2.

Extinguish with dry chemicals, alcohol foam, or carbon dioxide: Determined by Item 6.3, CG-446-2.

Extinguish with dry chemicals or carbon dioxide: Determined by Item 6.3, CG-446-2.

Do not use water on fire: Determined by Item 6.4, CG-446-2.

Do not use water or foam on fire: Determined by Item 6.4, CG-446-2.

Do not use water on adjacent fires: Determined by Item 6.4, CG-446-2.

Water may be ineffective on fire: Determined by Item 6.4, CG-446-2.

Cool exposed containers with water: Applies to all flammable liquids, flammable liquefied gases, flammable compressed gases, as well as polymerizable materials and irritating or toxic compressed gases.

Stop flow of gas if possible: Applies to all flammable liquefied and compressed gases.

Cool exposed containers and protect men effecting shutoff with water: Applies to all containers of flammable liquefied and compressed gases which may explode in a fire.

Let fire burn: See Explanation of Terms, CG-446-1.

Evacuate surrounding area: Applies to flammable and/or toxic compressed gases or any with explosion potential. See "Let fire burn", above.

Combat fires from safe distance or protected location: See Explanation of Terms, CG-446-1.

Combat fires from safe distance or protected location with unmanned hose holder or monitor nozzle: See Explanation of Terms, CG-446-1.

Combat fires from behind a barrier: See Explanation of Terms, CG-446-1.

Flood discharge area with water: See Explanation of Terms, CG-446-2, Item 1, Response to Discharge.

Ignites when exposed to air: Based on §7.2, CG-446-2.

Exposure

Call for medical aid: See Explanation of Terms, CG-446-1.

Poisonous if inhaled: See Explanation of Terms, CG-446-1.

Poisonous if inhaled or if skin is exposed: See Explanation of Terms, CG-446-1.

Irritating to eyes: Determined by Item 5.2, CG-446-2.

Irritating to eyes, nose, and throat: Determined by Item 5.2, CG-446-2.

If inhaled will cause (dizziness, coughing, difficult breathing, headache, loss of consciousness): Determined by Item 5.2, CG-446-2.

Harmful if inhaled: See Explanation of Terms, CG-446-1.

Not harmful: Determined by Item 5.2, CG-446-2.

Move victim to fresh air: Applicable to all chemicals that upon discharge, cause vapor or dust exposures. Applicable even if chemical is not harmful since the vapor can displace oxygen in the breathing air. See Item 5.3, CG-446-2.

If breathing has stopped, give artificial respiration: Applies to chemicals that produce harmful or poisonous vapors or dusts, or that may produce breathing interruption due to neurological effects. See Item 5.3, CG-446-2.

If breathing has stopped, give artificial respiration (but not mouth-to-mouth): See Explanation of Terms, CG-446-1; also see Item 5.3, CG-446-2.

If breathing is difficult, give oxygen: See Item 5.3, CG-446-2.

If in eyes, hold eyelids open and flush with plenty of water: See Item 5.4, CG-446-2.

Poisonous if swallowed: See Explanation of Terms, CG-446-1.

Poisonous if swallowed or if skin is exposed: See Explanation of Terms, CG-446-1.

Will burn eyes: See Item 5.2, CG-446-2.

Will burn skin and eyes: See Item 5.2, CG-446-2.

Irritating to skin and eyes: See Item 5.2, CG-446-2.

Irritating to eyes: See Item 5.2, CG-446-2.

Will cause frostbite: See Item 5.2, CG-446-2.

If swallowed, will cause (nausea, vomiting, loss of consciousness): See Item 5.2, CG-446-2.

Remove contaminated clothing and shoes: See Item 5.3, CG-446-2.

Flush affected areas with plenty of water: See Item 5.3, CG-446-2.

Do not rub affected area: See Item 5.3, CG-446-2.

If in eyes, hold eyelids open and flush with plenty of water: See Item 5.3, CG-446-2.

If swallowed and victim is conscious, have victim drink water or milk: See Item 5.3, CG-446-2.

If swallowed and victim is conscious, have victim drink water or milk and have victim induce vomiting: See Item 5.3, CG-446-2.

If swallowed and victim is unconscious or having convulsions, do nothing except keep victim warm: See Item 5.3, CG-446-2.

Do not induce vomiting: See Item 5.3, CG-446-2.

Pollution

Harmful to aquatic life in very low concentrations: See Explanation of Terms, CG-446-1.

Effect of low concentrations on aquatic life is unknown: See Explanation of Terms, CG-446-1.

Dangerous to aquatic life in high concentrations: See Explanation of Terms, CG-446-1.

Not harmful to aquatic life: See Explanation of Terms, CG-446-1.

Fouling to shoreline: Applies to insoluble, non-volatile liquids or solids which may float on water.

May be dangerous if it enters water intakes: Applies to all chemicals that are solids, liquids, or liquefied gases having a boiling point greater than 30°F.

Notify local health and wildlife officials: Applies to all chemicals that are solids, liquids, or potentially toxic soluble gases.

Notify operators of nearby water intakes: Applies to all chemicals except those whose boiling point is below 30°F and are insoluble.

APPENDIX D-I - Revised Specifications for CG-446-1

Condensed Guide to Chemical Hazards

Addendum (b) - Information on Explanation of Terms

Reprinted from CG-446-1

CONTENT

Chemical Identification Data

Chemical Name	The chemical name at the top of each page is the same as the name given in the Code of Federal Regulations. Many of the chemicals considered in this guide, however, are not listed in the Code of Federal Regulations; in such cases, the most common name is used. Data sheets are arranged alphabetically by chemical name; alphabetization is based on that part of the name which appears in capital letters. (Some chemical names have small-letter prefixes which do not determine the alphabetical arrangements.
Code	Each chemical is assigned a unique three-character alphabetic code for convenience in written or oral communication. These codes should be communicated by use of the phonetic alphabet and used along with complete chemical name. Where possible, the code corresponds to that commonly used in industry; in other cases, the code is made up of the first letter of the chemical name and two other letters generally derived from the remainder of the name. Note that the codes are not in strict alphabetical order (but chemical names are, of course): For example, BZD comes before BAD. Thus, when looking for a particular data sheet, use the chemical name and not the code as an alphabetical guide. A code-to-name conversion list is given in Section 9.
Common Synonyms	Selected, commonly used synonyms for the chemical are shown at the lower left corner of the chemical identification block. A more complete listing is given in the Thesaurus of Synonyms (Section 8).
Appearance	This box of the data sheet contains information on the physical state and color of the chemical as shipped, and on the odor and behavior of the chemical when discharged on water.
State:	The physical state describes the chemical as it is generally shipped: liquid, solid, gas, liquefied/compressed gas, or suspension. Solids are further identified as crystals, powders, lumps, granules, or pellets. The consistency of liquids is also described as watery, oily, or thick.
Color:	The color is that of the chemical as it is generally shipped. A range of colors is given if the material is dyed by manufacturers for ease of identification, or if it changes color when exposed to air or moisture.

Odor: Many odors are difficult to describe. General terms (sweet, pungent, irritating, etc.) are used in some cases. Whenever possible odors are compared with those of common materials.

Action on Release: Also given is a description of the behavior of the chemical when it is spilled on water -- that is, whether it sinks or floats and whether or not it mixes with water. If it reacts with water, releases a vapor cloud, or has some other special behavior, this is also noted. When a chemical boils or freezes (melts) at a temperature close to the temperature of the surroundings (30-100^{o} F), the boiling point or freezing point is listed. Except where otherwise noted, all vapors produced are heavier than air (i.e., they tend to sink or hug the ground unless heated).

General Response Information

The General Response Information section of the data sheet presents general responses to the discharge of the chemical. The order in which these responses are listed is important and should be followed if possible. While most of the phrases are self-explanatory, the following require additional clarification:

Goggles and self-contained breathing apparatus: Airtight goggles and a breathing apparatus with a compressed air supply or an oxygen generator should be worn to avoid irritating or poisonous vapors.

Rubber overclothing (including gloves): Rubber boots, coat (or apron and slee), and gloves are necessary for chemicals that will soak into normal clothing and cause skin burns or poisoning.

Isolate and remove discharged material: Removal procedures must be tailored to each specific situation. For example, materials discharged on wharves or on shore may be diked, while materials that float might be contained with boom. For more information on removal procedures, consult CG-446-4, Response Methods Handbook.

Chemical protective suit: A complete vapor-tight suit designed for the handling of reactive acids or chemicals is recommended where skin contact with the vapor is poisonous or where the chemical may corrode rubber or fabric overclothing.

Keep people away: This action is recommended for most compounds, as the number of people at risk in the area of a hazard discharge should be minimized.

Evacuate area: Discharge of poisonous gases or explosive materials can endanger surrounding areas. When evacuation is recommended, the area to be evacuated must be determined by on-scene personnel. Personal judgment can be supplemented by consulting the Hazard Assessment Handbook (USCG-446-3) or the Hazard Assessment Computer System (HACS).

Stop leak if possible:	An attempt should be made to limit or stop the rate of quantity of a discharge unless this action involves excessive danger to personnel. Hazard warnings in the Fire and Exposure Sections should be read before approaching the discharge source. If approach severely endangers personnel, do not attempt to stop the discharge.
Shut off ignition sources:	Highly flammable vapors may be ignited by sparks, motors, pilot flames, matches or cigarettes, or other heat sources. When securing potential sources of ignition, remember that the turning off of a switch may produce a spark that can cause ignition.
Call fire department:	It is advisable to call the fire department whenever a flammable or combustible chemical discharge occurs or threatens, even if the chemical is not on fire. (See Section 1, Notification.)
Stay upwind and use water spray to knock down vapor:	Flammable or irritating vapors can be partially dispersed by the use of a water spray or fog delivered from upwind. Straight streams of water should be avoided because they tend to splash and scatter the spill and may spread the hazard over a larger area.

Fire

The fire box on the data sheet gives warnings about any flammability hazards of the material or its vapors. Appropriate responses are also described in case the material is actually burning or is in the vicinity of a fire.

The following phrases are used to describe the hazards of fire:

Not flammable, flammable, or combustible:	Materials that burn are classified as either flammable or combustible. These classifications are according to definitions in the Code of Federal Regulations (Title 46, Subpart 146). Flammable liquids have a flashpoint of less than 80° F; combustible liquids are those with flashpoints higher than 80° F. (Flashpoint is the temperature at which a liquid will give off enough flammable vapors to ignite.)
Poisonous gas(es) may be (are) produced in fire or when heated:	Some chemicals containing halogens, sulfur, or nitrogen may or do produce poisonous gases upon combustion or decomposition. The free halogens, halogen acids and phosgenes; sulfur dioxide; and hydrogen cyanide are typical products for which this warning appears. Materials that produce poisonous gases upon evaporation due to heating from an adjacent fire are also included under this warning.
Containers may explode in fire:	This warning identifies chemicals that undergo a possibly dangerous change when heated. Materials that violently react with themselves at high temperatures (in chemical terms polymerize or decompose) or vaporize easily are labeled with this warning.

May cause fire on contact with combustibles: Some materials are not flammable themselves but can start fires by reacting with common combustible materials. These are "oxidizing agents", and are identified by the warning shown.

Flammable/poisonous gas is produced on contact with metals/water: This warning is intended for chemicals that can produce a flammable or poisonous gas (such as hydrogen or hydrogen chloride) upon contact with metals or water.

Vapor may explode if ignited in an enclosed area: If a flammable vapor should leak into an enclosed area and reach a certain level of concentration in air, ignition could cause an explosion.

Flashback along vapor trail may occur: Many flammable liquids and all flammable gases can produce a vapor cloud that can travel a considerable distance downwind. If the cloud should reach an ignition source, the flame may flash back to the source and ignite a fire there.

Under responses to fire, the following pertain to extinguishing agents:

Water: Always use water as a spray, never as a solid stream.

Foam: Protein or aqueous film-forming foams are effective on many chemicals that are insoluble in water but float on water. Strong wind reduces the effectiveness of foam.

Alcohol foam: Alcohol foam is used for liquids that mix with water. It has less mechanical strength than other foams, so it must be applied with care.

Dry chemicals: Sodium bicarbonate, potassium bicarbonate, and monoammonium phosphate are frequently found in portable and wheeled extinguishers. These are ideal for small liquid fires.

Carbon dioxide (CO_2): Carbon dioxide is a compressed inerting gas and is generally available in portable and wheeled units. It is not as effective as dry chemicals in extinguishing fires, particularly in the open air.

The following are some of the phrases that may also appear under responses to fire:

Water may be ineffective on fire: If the material is a very flammable liquid (with low flash point) or floats on water, then water may not extinguish the fire. Best results are obtained with a fine spray applied by experienced fire fighters.

Do not use water/foam: The use of water or foam increases the fire hazard of certain chemicals. These chemicals react with water, generating heat or poisonous or flammable gases.

Let fire burn: When a tank of a flammable compressed gas leaks, extinguishing the fire might permit the escaping vapor to build up to a dangerous concentration, drift over populated areas, and reignite, causing extensive damage. Unless the leak can be stopped, the fire should be allowed to burn until the fuel is spent. Adjacent property should be cooled with water.

Combat fires from safe distance or protected location (behind barriers) with unmanned monitor nozzle: When containers may explode or poisonous gases may be produced, no personnel should approach the fire. Fire fighters should be shielded from flying fragments that may result from container rupture or should keep a safe distance away. When a material can be detonated by exposure to heat, personnel should stay behind barriers that afford protection from blast waves. Use of a monitor nozzle if one is available and evacuation of the area as soon as possible are advisable.

Exposure

The Exposure box of the data sheet concerns the exposure of people to the discharged chemical in each of its physical states. The hazards and responses are based on information given in the Hazardous Chemical Data manual (USCG-446-2). Though most of the phrases in this section do not require explanation, some are clarified below.

Poisonous and Harmful: Chemicals that present a health hazard have been divided into two classes. Those chemicals that present the greatest health hazard are labeled "poisonous". Poisonous chemicals are those described as such by the Code of Federal Regulations (Title 46, Subpart 146). Chemicals labeled poisonous under the IMCO labeling systems are also included. For chemicals that are not classified by either of these systems, those with a Threshold Limit Value (TLV) of less than 1 ppm are considered poisonous (where TLV is the air-borne concentration believed to be safe for a long-term continuous exposure). The symptoms of exposure to poisonous materials are listed. Other chemicals do not present as severe a hazard as do poisons but are not entirely harmless. Materials that are recognized exposure hazards but are not "poisons" are noted in either of two ways:

a) When the symptoms of exposure are known, these are listed (e.g., "if inhaled will cause coughing and nausea."), or

b) When the symptoms are not known, the phrase Harmful if inhaled (or swallowed, etc.) is used.

The hazardous materials that are listed as harmful (or by symptom) have TLV values between 1 ppm and 100 ppm or LD_{50} values below 5 g/kg. (The LD_{50} is the amount of chemical that, when swallowed, will be fatal to 50% of those exposed. LD_{50} is expressed as weight swallowed/kg of body weight.)

Call for medical aid: This is a recommended response for exposure to all chemicals except those described as "Not harmful". When calling medical personnel, report:

- Material involved
- Nature of the exposure
- Victim's condition and location
- Time when exposure occurred.

Artificial respiration or oxygen: The appropriate action noted on the data sheet should be given if the victim's breathing pattern is in any way affected. Oxygen should not be administered for periods of more than one hour unless ordered by medical personnel. With Class A poisons the lethal dose is so small that mouth-to-mouth resuscitation may poison the person giving aid; another method of artificial respiration should be used in such cases.

Do nothing except keep victim warm: If the victim has swallowed a chemical and is unconscious or having convulsions, an attempt to induce vomiting or drinking could cause him to choke.

If swallowed and victim is conscious, have victim drink water or milk: This instruction appears whenever it is advisable to dilute the chemical that has been swallowed.

Do not induce vomiting: If vomiting will cause further damage to throat and esophagus, this warning appears. This response particularly applies to strong acids and bases, substances that burn, and petroleum products.

Do not rub affected areas: In cases of frostbite, permanent damage may result from rubbing.

Water Pollution

Any chemical discharged into water will, in high enough concentrations, be harmful to aquatic life. The Water Pollution box on the data sheet is used to highlight the compounds that are damaging when present even in very small amounts. Specific toxicity data on which these warnings are based can be found in the Hazardous Chemical Data manual (USCG-446-2). Explanation of some of the phrases follows:

Harmful to aquatic life in very low concentrations: If its median tolerance limit (TL_m) is less than 100 ppm (or 100 mg/1), a chemical is extremely hazardous to aquatic life even after considerable dilution. (TL_m is the concentration at which one-half of the aquatic life exposed will show some abnormal affects.)

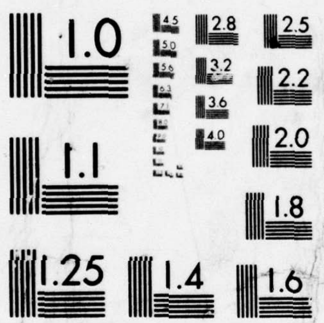
Effect of low concentrations on aquatic life is unknown: When aquatic toxicity data is unavailable, this warning is used. These materials, like most others, are hazardous in high concentrations.

Dangerous to aquatic life in high concentrations: When the TL_m of a chemical is above 100 ppm (or 100 mg/1), the primary hazard is from areas of high concentration where either toxicity or the lowering of dissolved oxygen levels may harm aquatic life.

AD-A034 655 LITTLE (ARTHUR D) INC CAMBRIDGE MASS F/G 5/2
DEVELOPMENT OF CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM (CH--ETC(U)
OCT 76 D S ALLAN, G H HARRIS DOT-CG-24655-A
UNCLASSIFIED ADL-C-74685 USCG-D-117-76 NL

3 OF 3
AD
A034655

END
DATE
FILMED
2-77



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

Not harmful to aquatic life: Compressed (and liquefied compressed) gases that are almost insoluble present no hazard to aquatic life.

May be dangerous if it enters water intakes: Any chemical entering an intake may present a hazard. Depending on what the water is used for, there may be danger of fire, poisoning, explosions, or corrosion.

Fouling to shoreline: Materials that float on water and do not dissolve readily or evaporate quickly can be washed ashore and damage valuable recreational areas, private property, and wildlife areas.

Notify operators of nearby water intakes: The locations and phone numbers of operators of water intakes can be found in the Regional Contingency Plan. These people should be notified of nearby discharges so that they can decide whether or not to close their intakes.

APPENDIX D-II

CG-446-2 Hazardous Chemical Data Publication Specifications

ORGANIZATION

The contents of manual CG-446-2 will be organized in the following manner:

Update Control

Table of Contents

1. Introduction
2. CHRIS Manuals
3. Explanation of Terms
4. Other Information Systems
5. Conversion Factors
6. Selected Properties of Fresh Water, Sea Water, Ice, and Air
7. Guide to Compatibility of Chemicals
8. Index of Synonyms
9. Index of Codes
10. Data Sources
    - 10.1 General Sources
    - 10.2 Chemical Designations
    - 10.3 Health Hazards
    - 10.4 Fire Hazards
    - 10.5 Water Pollution
    - 10.6 Physical and Chemical Properties
11. Chemical-Specific Information
    - 11.1 Condensed Guide Sheet
    - 11.2 Data
        - Item 1: Response to Discharge
        - Item 2: Labels
        - Item 3: Chemical Designations
        - Item 4: Observable Characteristics
        - Item 5: Health Hazards
        - Item 6: Fire Hazards
        - Item 7: Chemical Reactivity
        - Item 8: Water Pollution

Item 9: Selected Manufacturers

Item 10: Shipping Information

Item 11: Hazard Assessment Code

Item 12: Hazard Classifications

Item 13: Physical and Chemical Properties

FORMAT AND LAYOUT

Table of Contents

The table of contents will consist simply of a list of the 11 major sections.

Update Control

The Update Control section of manual CG-446-2 will consist of a series of un-numbered pages similar to that shown in Figure D-1-6. Each sheet will give the date of a particular revision or update to the manual and a summary of all sections and chemicals affected. Each Update Control page is to be signed by Coast Guard personnel and dated at the time the specified change is actually made to the manual. All Update Control pages should be retained in the manual so that users can verify that the information is current.

Compatibility Guide, Index of Synonyms, and Index of Codes

These three sections (7, 8, and 9) will be identical to those used in the Condensed Guide to Chemical Hazards, CG-446-1. However, as individual pages in that manual will not be dated, it will be necessary to add the date of issue to the pages in these sections when they are reproduced for CG-446-2 so that revisions can be identified.

Chemical-Specific Information

This section (11) will constitute the bulk of the manual. Most of the 400 chemicals initially included will require six pages each; an additional sheet may be needed for a few that have lengthy entries. Each page will be laid out according to a standard form, as shown in Figure D-1-7. Note that each displays the full chemical name and chemical code in bold, typeset letters as a running head. The size and location of the boxes and the wording of the section headings and subheadings will not vary from one chemical to the next.

Some of the physical and chemical properties of each chemical will be shown by means of graphs. There may be up to eight of these, and they will appear in consistent locations on the fifth and sixth pages of each chemical description. The graphs will be plotted by computer and mounted in the proper locations.

The first page of each chemical description will be, in essence, a reproduction of the corresponding page in manual CG-446-1. The only difference will be that "CG-446-1" will be deleted from the bottom margin and the appropriate date, page number, and manual number will be substituted.

Reproducible Copy

Reproducible copy is to be supplied final size and ready for camera. Separate copy is to be provided for any material to be printed in color and will be marked for proper registration. Pages will be 8-1/2 x 11 inches. Text will be single-spaced, justified, and set single-column in a medium-weight 11-point Roman face similar to Press Roman; a medium-weight 10-point sans-serif face similar to Universe may be used for tabular material. Margins shall be 1-1/4 inches on all sides. (Narrower margins and additional type faces are used in section 11; see sample in Figure D-1-7.

Each major section will begin on a right-hand page. Each of the sections except the last (11) will be individually paginated, section I starting with 1-1, section 2 with 2-1, etc. Section 11 will be paginated only within the individual 6- or 8-page set for a given chemical; thus, the numbers will run from 1 to 6 and then begin at 1 again. The 6- or 8-page sets will be arranged in alphabetical order according to the chemical name (not the chemical code).

Because sections 7, 8, 9, and 11 will be revised from time to time, each page in these sections will show the date of issue in the lower right corner. No company or agency logotype will appear on the pages of the manual.

Printing and Binding

Paper stock will be 70-pound white offset and will be printed on both sides. Since these manuals may see service, the use of a spunbonded,

coated synthetic paper (e.g., ASCOT or TYVEK) should be considered; such paper would be highly weather-resistant and could not be torn out of the binder accidentally.

All printing will be in black except for portions of section II, where all page 1's will have some text in red and many page 2's will display labels that must be printed in red, green, blue, orange, or yellow. Color may also be used on the cover sheet, if desired.

Vinyl-covered four-ring looseleaf binders will be supplied by the Coast Guard. Since each binder holds approximately 200 sheets, six or seven will be required for each complete copy of the manual. These will be designated Volume I, Volume II, etc. An appropriate cover will be designed for the manual and printed for insertion in the transparent pocket on the front of the binder for each volume; the volume number will appear beneath the manual designation. Similarly, copy will be supplied for an identifying strip to be inserted in the spine of the binder; this will show the title of the manual, its numerical designation, and the volume number.

CHRIS MANUAL CG-446-2

HAZARDOUS CHEMICAL DATA

REVISION 3: December 20, 1973

SECTION 7

Replace pp. 7-3, -4, -7, and -8.

SECTION 8

Replace pp. 8-9 and -10.

SECTION 9

Replace pp. 9-3 and -4.

SECTION 11

Replace pp. 1, 2, 3, and 4 for ETHYLENE.

Insert THYMYLAMINE (pp. 1 through 6) after TETRAMETHYL LEAD.

Replace pp. 5 and 6 for VINYL CHLORIDE.

Manual updated by____________________

Date____________________

Dec. 1973

Figure D-I-6: Sample Update Control Sheet

Figure D-I-7: Sample of Section 11 (page 1 of 6 pages)

HYDROCHLORIC ACID	HCL

Common Synonyms			
Muriatic Acid	Watery liquid	Colorless	Sharp, irritating odor
	Sinks and mixes with water. Irritating vapor is produced.		

AVOID CONTACT WITH LIQUID AND VAPOR. Keep people away.
Wear chemical protective suit with self-contained breathing apparatus.
Stop discharge if possible.
Stay upwind and use water spray to "knock down" vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire	**Not flammable.** **Flammable gas may be produced on contact with metals.** Wear chemical protective suit with self-contained breathing apparatus.
Exposure	CALL FOR MEDICAL AID. **VAPOR** **Irritating to eyes, nose and throat.** **If inhaled, will cause coughing or difficult breathing.** Move to fresh air. If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen. **LIQUID** **Will burn skin and eyes.** **Harmful if swallowed.** Remove contaminated clothing and shoes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water. IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk. DO NOT INDUCE VOMITING.
Water Pollution	**Dangerous to aquatic life in high concentrations.** **May be dangerous if it enters water intakes.** Notify local health and wildlife officials. Notify operators of nearby water intakes.

CG 446-1

HYDROCHLORIC ACID | HCL

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-4)

Issue warning—corrosive
Restrict access
Disperse and flush

2. LABELS

PRESENT

NEW

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Muriatic acid

3.2 **Coast Guard Compatibility Classification:** Inorganic acid

3.3 **Chemical Formula:** $HCl\text{-}H_2O$

3.4 **IMCO/United Nations Numerical Designation:** 8.0/1789

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid

4.2 **Color:** Colorless to light yellow

4.3 **Odor:** Pungent; sharp, pungent, irritating

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Self-contained breathing equipment, air-line mask, or industrial canister-type gas mask; rubber or rubber-coated gloves, apron, coat, overalls, shoes.

5.2 **Symptoms Following Exposure:** Inhalation of fumes results in coughing and choking sensation, and irritation of nose and lungs. Liquid causes burns.

5.3 **Treatment for Exposure:** INHALATION: remove person to fresh air; keep him warm and quiet and get medical attention immediately; start artificial respiration if breathing stops. INGESTION: have person drink water or milk; do NOT induce vomiting. EYES: immediately flush with plenty of water for at least 15 min. and get medical attention; continue flushing for another 15 min. if physician does not arrive promptly. SKIN: immediately flush skin while removing contaminated clothing; get medical attention promptly; use soap and wash area for at least 15 min.

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 5 ppm

5.5 **Short-Term Inhalation Limits:** Data not available

5.6 **Toxicity by Ingestion:** Data not available

5.7 **Late Toxicity:** None

5.8 **Vapor (Gas) Irritant Characteristics:** Vapor is moderately irritating such that personnel will not usually tolerate moderate or high vapor concentrations.

5.9 **Liquid or Solid Irritant Characteristics:** Fairly severe skin irritant; may cause pain and second-degree burns after a few minutes' contact.

5.10 **Odor Threshold:** 1-5 ppm

HCL | HYDROCHLORIC ACID

6. FIRE HAZARDS

6.1 **Flash Point:** Not flammable

6.2 **Flammable Limits in Air:** Not flammable

6.3 **Fire Extinguishing Agents:** Not pertinent

6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent

6.5 **Special Hazards of Combustion Products:** Toxic and irritating vapors are generated when heated.

6.6 **Behavior in Fire:** Not pertinent

6.7 **Ignition Temperature:** Not flammable

6.8 **Electrical Hazard:** Not pertinent

6.9 **Burning Rate:** Not flammable

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** Corrosive to most metals with evolution of hydrogen gas, which may form explosive mixtures with air.

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Flush with water; apply powdered limestone, slaked lime, soda ash, or sodium bicarbonate.

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:**
282 ppm/96 hr/mosquito fish/TL_m/fresh water
100-330 ppm/48 hr/shrimp/LC_{50}/salt water

8.2 **Waterfowl Toxicity:** Data not available

8.3 **Biological Oxygen Demand (BOD):** None

8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Diamond Shamrock Corp.
Electro Chemicals Division
300 Union Commerce Bldg.
Cleveland, Ohio 44115

2. Stauffer Chemical Co.
Industrial Chemicals Division
299 Park Ave.
New York, N. Y. 10017

3. Vulcan Materials Co.
Chemicals Division
Wichita, Kan. 67201

10. SHIPPING INFORMATION

10.1 **Grades or Purity:**
Food processing or technical:
18° Be—27.9%, 20 Be—31.5%,
22° Be—35.2%;
Reagent, ACS, and USP: 23° Be—37.1%

10.2 **Storage Temperature:** Ambient

10.3 **Inert Atmosphere:** No requirement

10.4 **Venting:** Open

HYDROCHLORIC ACID — HCL

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-P

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:**
Corrosive material

12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	0
Health	
Vapor Irritant	3
Liquid or Solid Irritant	3
Poisons	2
Water Pollution	
Human Toxicity	2
Aquatic Toxicity	2
Aesthetic Effect	2
Reactivity	
Other Chemicals	3
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	3
Flammability (Red)	0
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES*

13.1 **Physical State at 15°C and 1 atm:** Liquid

13.2 **Molecular Weight:** Not pertinent

13.3 **Boiling Point at 1 atm:**
123°F = 50.5°C = 323.8°K

13.4 **Freezing Point:** Not pertinent

13.5 **Critical Temperature:** Not pertinent

13.6 **Critical Pressure:** Not pertinent

13.7 **Specific Gravity:** 1.19 at 20°C (liquid)

13.8 **Liquid Surface Tension:** Not pertinent

13.9 **Liquid-Water Interfacial Tension:**
Not pertinent

13.10 **Vapor (Gas) Specific Gravity:**
Not pertinent

13.11 **Ratio of Specific Heats of Vapor (Gas):**
Not pertinent

13.12 **Latent Heat of Vaporization:**
(est.) 130 Btu/lb = 72 cal/g = 3.0×10^5 J/kg

13.13 **Heat of Combustion:** Not pertinent

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** (est.) −26 Btu/lb
= −14 cal/g = 0.6×10^5 J/kg

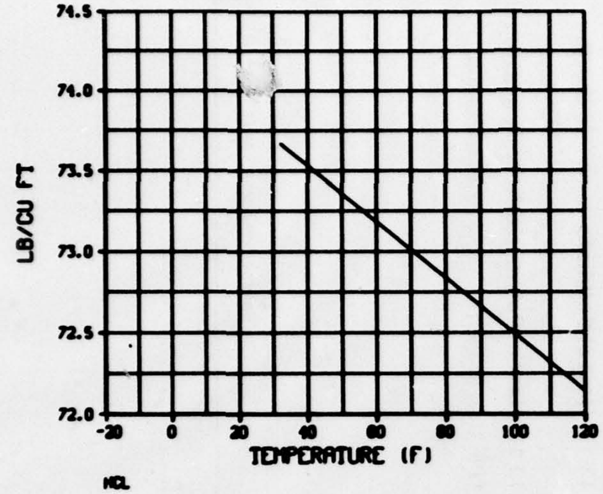
13.16 **Heat of Polymerization:** Not pertinent

*Physical properties apply to 37% solution.

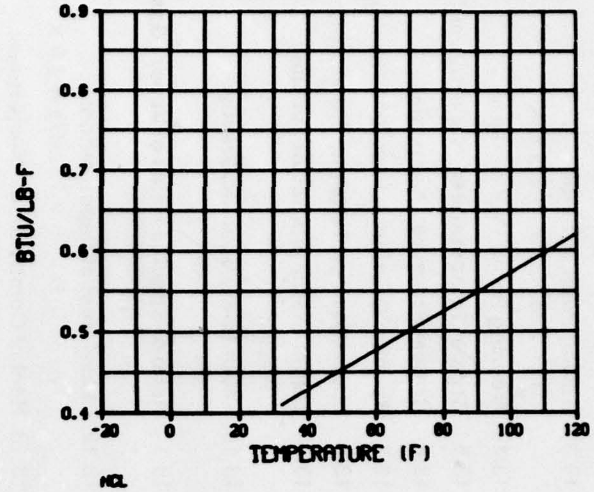
(Continued on pages 5 and 6)

NOTES

13.17 SATURATED LIQUID DENSITY



13.18 LIQUID HEAT CAPACITY



13.19 LIQUID THERMAL CONDUCTIVITY

NOT PERTINENT

HCL

13.20 LIQUID VISCOSITY

NOT PERTINENT

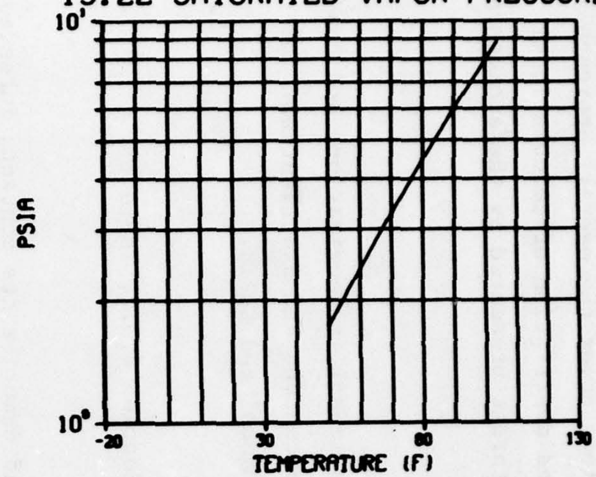
HCL

13.21 SOLUBILITY IN WATER

MISCIBLE

HCL

13.22 SATURATED VAPOR PRESSURE



HCL

13.23 SATURATED VAPOR DENSITY

NOT PERTINENT

HCL

13.24 IDEAL GAS HEAT CAPACITY

NOT PERTINENT

HCL

APPENDIX D-III

Specifications for CG-446-3

Hazard Assessment Handbook

Specifications for the content of the Hazard Assessment Handbook are presented here. These specifications cover the overall approach to hazard assessment, the selection and description of calculational procedures, and the evaluation of the threat presented by the accidental release of a hazardous chemical.

Preface

Cite the purpose and scope of the manual, authorization, and Coast Guard component(s) responsible for the content and distribution. Describe the relationship between this manual and CHRIS.

Table of Contents

Cite the Table of Contents (see Section 4.3.2, Table 2).

CHRIS Manuals

List each of the CHRIS manuals and describe its content, intended use, and relationship with this manual.

Overall Approach

Present the overall approach to the assessment of hazards resulting from the accidental release of a hazardous chemical. Provide step-by-step procedures to be employed for hazard assessment, including the gathering of information, different levels of assessment, and the evaluation of the potential threat.

Information Needs

Cite methods and information required to conduct both a preliminary (short-term) and a detailed assessment of the potential threat presented by an accidental release, as follows:

1. Organization of Information Needs

Briefly summarize the content and need for the information to be derived by the use of this chapter.

2. Primary List of Questions

Cite the questions that may have to be answered in order to perform a hazard assessment for a specific hazardous chemical discharge. These questions should result in information on the identity of the chemical, the time and location of the discharge, on the quantity discharged, and on the meteorological and hydrological conditions that exist at the time and site of the discharge.

3. Secondary List of Questions

Cite additional questions whose answers may serve to allow partial validation and refinements of the hazard assessment. These questions should result in further information on the identity of the chemical, the amount spilled, action of the chemical when discharged and on existing meteorological and hydrological conditions.

4. List of Information Sources

Cite a brief list of sources which may be contacted to facilitate obtaining the information needs and answering the primary list of questions.

5. Detailed Description of Information Sources

Cite alternate sources and other means by which both the primary and secondary list of questions may be answered.

Selection of Calculation Procedures

Develop and describe an organized method of selecting the calculation procedures for estimating the movement and dispersion of the chemical that is released. It is recommended that the procedures follow the outline used in the existing manual.

Hazard Assessment

In this section cite the primary hazard assessment codes, the hazard calculation code and develop work-sheets for exercising the actual code. Cite the background information needed to proceed with the assessment and provide a sample calculation on the draft side of the page with blanks on the right side where actual calculations can be made.

Figures and Tables

Present a complete set of figures and tables necessary for hazard assessment. Arrange them alphabetically by assessment code.

Accuracy of the Hazard Assessment

Cite the level of accuracy associated with the assessment output.

Use of HACS

Cite how a field user may contact CHRIS headquarters and request a HACS output to better assess a spill hazard.

Appendices

Present appendices which may be useful in field use of the manual. As a minimum, an appendix of useful conversion factors and an appendix containing an explanation of terms must be presented.